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FREQUENCY RESPONSE EVALUATION OF MULTIPLE ACCELEROMETERS USING A MODEL DATA ACQUISITION SYSTEM

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NOTICE

This technical report has been reviewed and is approved for publication.

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This report describes a technique to get complete frequency response calibrations of 15 accelerometer channels at a time. The accelerometers were mounted to a rigid circular plate attached to a shaker excited by random noise. A digital pulse code modulation data acquisition system acquired and stored the 15 responses. Using the time multiplexed, digital responses, each transducer frequency response was computed by deriving transfer functions between the 15 unknown transducers and a DC responding reference accelerometer. Before using this multiple accelerometer calibration technique, several single channel laboratory calibrations were performed using four methods. The multiple accelerometer technique was tested in the laboratory and on a F-16 wing ground vibration test. A total of 37 accelerometers were evaluated over a range of 0 to 100 Hz.

Exciting multiple accelerometers ensures calibration of each transducer at the same temperature, humidity, and force input levels. The technique provides a quick, automated, end-to-end frequency response calibration. Sensitivities versus frequency are close to those obtained using single accelerometer calibration techniques.

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FOREWORD

This effort was performed by the Structural Dynamics Branch (AFWAL/FIBG) of the Structures Division (AFWAL/FIB), Flight Dynamics Laboratories (AFWAL/FI), Air Force Wright Aeronautical Laboratory (AFWAL), Wright-Patterson Air Force Base , Ohio. The effort supported AFWAL/FIBG in-house Project 24010402, "Instrumentation, Facilities and Techniques for Obtaining Dynamics and Loads Data on Air Force Weapon Systems." Dave Banaszak was the project engineer, assisted by Jack Schmermund and Arnel Pacia. Earl Rogers and Mike Banford designed and fabricated the filter card systems and shaker control system. Lowell Vaughn, Larry Dukate and Dansen Brown provided the detailed data analysis and Jerry Plzak provided valuable counsel. John Self patiently set up the tape recorder transport. Carrie Waugh provided typing help. This manuscript was released by the author in December 1987 as a FIBG Test Report.

The report has been reviewed and is approved.

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1 INTRODUCTION

Structural Dynamics Branch (FIBG) performs many ground vibration tests (GVTs) requiring large numbers of accelerometers. Recent GVTs include a F-16 aircraft, two F-16 wings and an A-7D aircraft (References 1-3). These GVTs required measuring 37 to 120 accelerometer outputs during one data record. GVTs require the sensitivities and frequency response of many transducers. The multiple accelerometer calibration technique used on the F-16 wing GVT provided accurate and rapid frequency response calibrations. The technique used a reduced version of the pulse code modulation (PCM) data acquisition system used on the F-16 aircraft GVT as described in references 4 and 5. This report describes and compares results of single accelerometer calibrations with multiple accelerometer calibrations for the 37 accelerometers used on the F-16 wing GVT.

2 FREQUENCY RESPONSE CALIBRATIONS USING RANDOM NOISE

2.1 Frequency Response Theory

Before proceeding, a short explanation of frequency response calibrations using random noise excitation and a reference transducer is presented. An oscillator can sweep frequencies and provide voltage inputs into linear systems. Measuring the ratio of output voltage versus input voltage for each frequency yields a frequency response. A frequency response can also be done with a dual-channel spectrum analyzer with random noise excitation and transfer function measurement capability.

Random noise excitation of an unknown and a reference transducer with the same g level can be used to obtain frequency response calibrations of the unknown transducer. The unknown sensitivity is the voltage transfer function H(f) between transducer outputs multiplied by the reference sensitivity. For a reference accelerometer with a sensitivity Sr(f) V/g for each frequency f we have the following:

$$Vr(f) = Sr(f) \times Gr(f)$$
$$Vu(f) = Su(f) \times Gu(f)$$

so that

$$H(f) = \frac{Vu(f)}{Vr(f)} = \frac{Su(f) \times Gu(f)}{Sr(f) \times Gr(f)} = \frac{Su(f)}{Sr(f)} \tag{1}$$

then $$Su(f) = H(f) \times Sr(f) \tag{2}$$

where H(f) = Transfer Function
Gu(f) = Gr(f) = G = Number of g applied to the transducers
Su(f) = The unknown sensitivity in volts/g
Sr(f) = The known sensitivity of the reference transducer
Vu(f) = The voltage out of the unknown transducer
Vr(f) = The voltage out of the reference transducer

The acceleration, G, into each transducer is the same if the transducers are mounted close to each other.

2.2 A Note On Sensitivity Units

For field use, a sensitivity in terms of volts/g as show above is desirable. Sensitivities in terms of counts/g are more compatible with digital systems. For the above, the results are analogous if the outputs are changed from volts to counts. However, conversion from counts/g to volts/g requires a linear correction equal to the A/D converter's input voltage range divided by 2**N, where N is the number of bits in the A/D converter.

3 SINGLE ACCELEROMETER LABORATORY CALIBRATIONS

During October 1986, FIBG evaluated 37 PCB Model 330A accelerometers using four methods: 1) Excitation with a 1 g rms handheld vibration calibrator, 2) Excitation with a 1 g peak desktop vibration calibrator, 3) Excitation of a tabletop shaker with random noise to obtain transfer function versus a high frequency reference accelerometer and 4) Excitation of a tabletop shaker with random noise to obtain a transfer function versus a DC responding accelerometer.

3.1 Single Point, Single Frequency Sensitivities

For method 1 a Bruel and Kjaer Type 4294 handheld calibrator was used to excite each accelerometer at 1 g rms and a frequency of 159.2 Hz. The resultant voltage sensitivities are tabulated in column 4 of Table I. A Bruel and Kjaer Type 4291 desktop calibrator excited each accelerometer at 1 g peak and a frequency of 79.6 Hz. The resultant voltage sensitivities are in column 5 of Table I. Column 1 of Table I shows each accelerometer's serial number (PCB SN).

3.2 Frequency Response Calibration

Figure 1 shows the instrumentation setup to perform methods 3 and 4 using random noise excitation to obtain frequency response measurements. The tranducers were mounted on a round plate, 3 inches in diameter by 5/16 inches thick as shown in the figure. The Setra Model 141A reference accelerometer was attached to the plate with screws. The unknown PCB and Columbia 902H reference accelerometer were mounted with double stick tape.

Method 3 allowed measurement of the higher frequency characteristic of the accelerometers. The sensitivity of the Columbia 902H reference accelerometer was found by using the 1 g peak desktop calibrator. This sensitivity was used on Channel A setup of the dual channel spectrum analyzer as shown in Figure 2. Then for each PCB accelerometer, a transfer function measurement was made and plotted from 0 to 5 kHz, as shown in Figures 3-39. The figures show the magnitude on top and phase on the bottom for each accelerometer serial number. The amplitude has a resonant peak and and a phase shift of -90 degrees as expected for a typical accelerometer frequency response. Column 3 of Table I shows the sensitivities that were read off these transfer functions at a frequency of 500 Hz.

Next, method 4 was used to determine the lower frequency characteristics of the 37 accelerometers. First, a three point, static earth calibration was performed on the Setra accelerometer and a least-squares best fit straight line was fitted to determine the sensitivity of 49.4 mV/g, as shown in Figure 40. This sensitivity was applied to the Channel A setup of the dual channel analyzer as shown in Figure 41. Then, for each PCB, the output was connected to Channel B of the analyzer to obtain and plot the transfer functions from 0 to 200 Hz as shown in Figures 42-78. The top plot of each figure shows each accelerometer had a flat amplitude response from near 0 Hz up to 200 Hz. The bottom plot shows coherence of close to one over most of the frequency range. Column 2 of Table I shows the underlined sensitivity read off these transfer function plots at a frequency of 80 Hz. The detailed procedures to obtain lower frequency transfer functions are included as Table II. A similar procedure was also used for the higher frequency transfer functions.

3.3 Summary Single Accelerometer Laboratory Calibrations

Examining Table I, little difference is seen in the sensitivities obtained at frequencies of 80, 500, 159 and 79 Hz when using each of the four methods. The values from the transfer functions at 80 Hz between the PCBs and Setra were used for comparison with multiple accelerometer calibrations.

4 MULTIPLE TRANSDUCER ACCELEROMETER FIELD CALIBRATIONS

Before the field test, a laboratory pretest of multiple accelerometer-calibrations was made using the set up in Figure 79. Figure 80 shows the block diagram of the instrumentation used on the F-16 wing GVT from April to August 1987. Before the GVT, an end-to-end multi-accelerometer calibration of fifteen PCBs at a time was accomplished using sine excitation and random noise excitation. For each set of fifteen accelerometers, the same signal conditioning and wiring were used for calibration as was used for actual recording of GVT data. This was done by moving the array of 15 accelerometers with wiring intact from the aircraft wing to the calibration shaker platform. Sine and random excitation accelerometer outputs were recorded on tape. After the calibration record, the accelerometer and wiring were moved back on the wing.

4.1 Multiple Accelerometer Calibration Instrumentation

In Figure 80, each accelerometer signal was conditioned in the signal conditioning rack with the same PCB amplifier, low pass filter and automatic gain control amplifiers as were used in the laboratory pretests, before input into a Pulse Code Modulation(PCM) Encoder. The encoder sequentially sampled and

digitized the data into a stream of 12 bit serial PCM words at a rate of 200 kbps. The encoder's A/D converted -2.5 volts to +2.5 volt accelerometer outputs into digital words of 0 to 4095 counts. Each word was sampled 347 2/9 times per second, as shown by the PCM format in Table III. The output of the PCM encoder was routed into a tape recorder and a PCM decommutation system. Each of the 37 PCB accelerometers were assigned a word number per Table IV. The reference Setra was input into word 40.

4.2 Static Calibration Of Reference Accelerometer

A three point calibration was done by turning the accelerometer every ten seconds to get +1g, 0g, -1g, 0g and +1g static inputs. The data were displayed every 5 seconds on the PCM decoder system. Calibrations were recorded on tape before each multiple accelerometer calibration as shown in the tape log in Table V. The data on tape were transferred in the lab onto a VAX 11/780 compatible tape for plotting the time histories in Figure 81. Using mean counts from the time histories for each g level, a best fit straight line was fitted to get counts/g for the Setra, as shown in Figure 82.

4.3 Sine Wave Calibration On Multi-transducer Platform

Fifteen PCB accelerometers and one Setra Accelerometer were mounted with double stick tape on the 3 1/2 inch diameter by 5/16 inch thick circular, rigid aluminum plate on the shaker shown in Figure 83. The shaker was excited at a frequency of 25 Hz at about 1 g rms using the Setra's sensitivity and monitoring the encoder's word 40. When the g level stabilized, the gains were fixed and the PCM decommutation system was set to view and print the amplifier gains.

After a voice record was made, PCM data were recorded for about two minutes. The recorded data were played back thru the PCM decoder to check bit sync and frame lock and to certify data quality.

4.4 Frequency Response Calibrations Using Random Noise Excitation

With the accelerometers mounted the same as for the sine test, a three point calibration record was made. Each three point calibration were recorded so that analysis personnel could derive a reference sensitivity for the transfer function calibrations. Since three point calibrations did not change significantly, the first three point calibration was used throughout. After mounting the Setra reference on the plate, the shaker was excited with random noise. While viewing gain codes on the PCM decoder for each PCB word, the level of the noise was increased until 0 dB gain was on each channel. The gains were inhibited after a quick look at the output of each word to ensure there was no clipping. A recording was made on tape as shown in Table V.

4.5 Multiple Accelerometer Calibration Analysis

Analysis personnel (FIBGA) transferred the calibration data records to digital computer tapes and then plotted time histories of the sine wave calibration records as shown in Figures 84 to 88. The random noise calibration records were plotted as transfer function (H(f)) amplitudes in terms of counts/g sensitivities for each PCB accelerometer versus the filtered Setra on word 40 as shown in Figures 89 to 125 all transfer functions were smooth looking except for word 28 in Figure 116. Also, the Setra was on word 39(not filtered) for checking frequency response and phase match as desired. On the included plots,

the PCB's sensitivities in counts/g can be read directly for frequencies from 0-100 Hz. FIBGA averaged the sensitivities for 5 Hz bandwidths to get the counts/g shown in Table VI. The center frequency of 25 Hz was choose in Table VI for comparison with single transducer laboratory calibrations and the 25 Hz sine wave field calibrations.

The data from the sine wave calibration used two methods to derive sensitivity: 1)Difference between maximum and minimum count values and 2) use of the mean and rms values in terms of counts. The max, min, mean and rms values were read from the time history plots. A BASIC program used the following equations for computing sine sensitivities:

S(25) = [(Cmax - Cmin)/2]/[(Gmax - Gmin)/2] (3)

where Cmax = Maximum Counts from the Sine Record

Cmin = Minimum Counts from the Sine Record

Gmax = Maximum g from Sine Record with 3 point calibration applied

Gmin = Minimum g from Sine Record with 3 point calibration applied

and

Csigma = SQR[(rms)**2 - m**2] counts (4)

Gsigma = SQR[(rms)**2 - m**2] g (5)

so S(25) = Csigma/Gsigma (6)

where SQR = Square Root , ** = exponentiation

sigma = standard deviation = SQR(sigma**2)=SQR(variance)

rms = root mean square

m = mean

S(25)= Sensitivity in counts/g at f = 25 Hz

The sine and averaged random noise data about f = 25 Hz in counts/ g were typed into a laptop computer as shown in Table VII. The BASIC program derived the random noise g/count at 0 dB for the sensitivity required by FIBGA's computer analysis programs. The program also derived the transducer's volts/g and the percent difference from the Oct 86 laboratory calibrations using the random noise and sine data. The output table from this program is shown as Table VIII.

4.6 Phase Correction Discussion

Since the Setra signal recorded on word 40 was filtered with an 80 Hz low pass filter like the PCBs, there should be no phase difference between the PCB and the Setra over the calibration frequency range. Random noise was inserted into each filter and transfer functions between input and output were plotted and compared and found to have good phase match between filters. Also the Setra was recorded unfiltered on word 39 so that programs can compute filter phase characteristics for the random noise calibration records. However, the resultant phase of a typical computed transfer function shown in Figure 126 for word 1 versus word 40 was not a constant 0 degrees. Likewise, word 1 versus unfiltered word 39 does not have the proper phase of 270 degrees at the filter cutoff as expected for a four-pole low-pass Butterworth filter. The reason for this discrepancy is that the computer programs assume all samples occur at the same time instant. This was not true with the PCM encoded data, as can be seen from the sample rates in Table III. For this test the following applies:

12 bits/word / 200kbps = .000060 seconds delay between adjacent words.

Then the appropriate phase correction at frequency f is as follows:

Phase(f)=(n1-n2)*(delta t /T)*360 = f*(n1-n2)*delta t

where n1 = First word number, n2 = Second word number

delta t = seconds delay between adjacent words

T = 1/f, where f = frequency of interest

Substituting values for word 40 versus word 1 at 100 Hz, we have:

Phase(100)=(40-1) * (.00006/.01) * 360 = 84.25 degrees

introduced by the computer, as shown in Figure 126.

The computer program must account for time delay between samples by correcting the phase of the transfer function by the above equation. If the data acquisition uses simultaneous sample and hold multiplexers, the above correction can be eliminated.

5 SUMMARY OF RESULTS

Table VIII shows the comparison of the sensitivities at a frequency of 80 Hz from the single channel laboratory tests(column 2 of Table I) and the results of multiple accelerometer calibrations using the sine wave and random noise excitation methods. The computation methods were as follows: sine derived sensitivity using the maximum and minimum values, sine derived sensitivities using the rms and mean values and the random noise derived sensitivities. Equations for the sine derivations were included above as Equations (3) and (6).

Using sine sensitivities derived from the maximum and minimum, all 37 sensitivities except word 28(SN1255) were less than 7% different. The 16.5 % difference in word 28 was due to 60 Hz noise as seen in the time history in Figure 123. Using sine sensitivities derived from the rms and mean, all sensitivities had less than 5 % difference except for word 3 (SN1089).

As seen from the table there is less than 6% deviation between the Oct 86 lab sensitivities and the April 87 multiple-accelerometer sensitivities using random noise excitation. Also, except for 60 Hz noise, the frequency responses of all sensors were flat over the range of interest. Even word 28(SN1255), which had a ragged looking transfer function, computed close to the laboratory calibration.

6 RECOMMENDATIONS

Preliminary results of exciting 37 PCBs mounted on a 1/2" thick by 4-3/8" diameter aluminum plate indicate that the multiple transducer technique can be expanded with good coherence over the range of modal testing. The limitations on the number of transducers are wiring complexity, weight of the mounting versus shaker drive capability and number of channels available on the data acquisition system.

The PCM decoder used on the wing modal test contained a DEC microVAX. Thus analysis programs ran on the VAX 11/780 might be used on the on site microVAX. This requires upgrading the PCM decoder with the data formatting options which writes the PCM data onto a tape or disk drive. Then the stored data can be reformatted to run with current FIBG analysis software. Then on site frequency response calibrations could be made quickly. Any multiple transducer

measurement program would benefit from this enhanced capability.

The random noise excitation technique was also used to get the response of the force gages for the test, but only one force gage could be calibrated at a time. An additional correction for mass was required to get pounds per counts.

The multiple tranducer, random noise excitation would probably give reasonable transfer function dynamic calibration of microphone and pressure transducers mounted as an array inside a cavity.

7 CONCLUSIONS

Use of the modal data acquisition system in the multiple transducer calibration system worked well. Advantages include the ability to obtain a large number of transducer frequency response functions in a matter of hours rather than a matter of days. Each transducer is excited at all frequencies in the same environment. Comparison with the single channel and multi-channel cases showed good repeatability. An end-to-end system frequency response calibration is available. For the F-16 wing test, the calibration and signal conditioning were the same. Since transfer functions from a reference are used, the amplitude of the excitation need not be held at a precise value such as 1 g rms. For low frequencies, the shaker output needs to be higher to get good coherence.

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9 TABLES

I Laboratory Sensitivities And Frequency Responses (Oct 1986) -

PCB SN	Method 4 H(f) PCB vs Setra SN120511 @80 HZ 49mv/g (2)V/g	figure	Method 3 H(f) PCB vs Columbia902 SN381 @500 HZ 9.3mv/g V/g	figure	Method 1 1grms Shaker f=159 Hz Imp-sine V/g	Method 2 1-gpeak Shaker f=79 Hz Computed from Imp-sine (V/gpk)x1.414(2)
857	1.17	42	1.17	3	1.20	1.20
1091	1.09	43	1.15	4	1.13	1.13
1076	1.02	44	1.02	5	1.05	1.06
1063	1.19	45	1.19	6	1.22	1.23
936	1.22	46	1.22	7	1.23	1.24
1089	1.07	47	1.10	8	1.09	1.10
1016	1.08	48	1.10	9	1.10	1.10
970	1.02	49	1.05	10	1.03	1.04
1134	1.14	50	1.16	11	1.15	1.16
1101	1.16	51	1.19	12	1.18	1.18
889	1.11	52	1.16	13	1.13	1.13
907	1.14	53	1.20	14	1.17	1.15
892	1.07	54	1.12	15	1.09	1.07
841	1.23	55	1.17	16	1.24	1.26
546	1.18	56	1.17	17	1.20	1.21
818	1.17	57	1.16	18	1.19	1.19
867	1.13	58	1.12	19	1.17	1.18
1139	1.13	59	1.17	20	1.20	1.21
1153	1.06	60	1.07	21	1.09	1.10
1170	1.13	61	1.12	22	1.16	1.17
1174	1.04	62	1.05	23	1.06	1.06
1193	1.05	63	1.06	24	1.09	1.09
1208	1.17	64	1.14	25	1.17	1.18
1210	1.14	65	1.12	26	1.14	1.15
1212	1.18	66	1.14	27	1.21	1.21
1213	1.12	67	1.10	28	1.14	1.15
1215	1.14	68	1.12	29	1.15	1.16
1218	1.15	69	1.14	30	1.17	1.17
1219	1.06	70	1.04	31	1.05	1.04
1234	1.04	71	1.02	32	1.07	1.03
1237	1.12	72	1.14	33	1.15	1.16
1242	1.11	73	1.11	34	1.13	1.13
1243	1.02	74	1.04	35	1.06	1.05
1247	1.13	75	1.12	36	1.16	1.16
1249	1.10	76	1.15	37	1.12	1.13
1255	1.11	77	1.10	38	1.12	1.15
1258	1.04	78	1.04	39	1.04	1.06

NOTES: (1) Temperature between 70-71 degrees F on 10/10-11/1986 for H(f).
(2) V/g = volts rms per g rms, V/gpk = volts rms per g peak.

II Laboratory Transfer Function Procedures -

1. Setup and Power up equipment.
   a. Setup equipment per Figure 1.
   b. Plug in PCB power cord.
   c. Turn on Wavetek spectrum analyzer.
   d. Turn on HP9870A digital plotter.
   e. Turn on power supply for Setra accelerometer and adjust for 15VDC.
   f. Turn on power amplifier and press reset.

2. Setup Wavetek 5820B spectrum analyzer.
   a. Set up channel A for 4.95 E-02 volts/ref (ie.49.5 mv/G for Setra).
   b. Set tracking signal(TSA) for random noise.
   c. Set Channel A sensitivity (SN=-20dBv or 100 mv) (200mv=4g SN867).
   d. Set channel B sensitivity (SN= +6dBV or 2.0v) (4.5 v~4.5g SN120511).
   e. Set Display Format for linear.
   f. Set Span for DC -200 Hz.(or other range of interest)
   g. Set N for 16 averages.
   h. Set Recording for digital plotter.
   i. Match View Setup with attached Figure 2.
   j. Setup plot display to match attached spectra scales or Figure 3.
   k. Set random noise out of analyzer about 1/2 way up.

3. Provide shaker excitation.
   a. Check that random noise out of analyzer is about 1/2 way.
   b. Adjust power amp output level until overload light barely stays off.
   c. Observe shaker amplitude while adjusting power amp output.

4. Acquire Transfer Functions and make plots.
   a. Insert plotter paper with serial number and date in top right.
   b. Press Start Processing on analyzer.
   c. Wait until light stops blinking.
   d. Press Stop Processing on analyzer.
   e. Press Start Recording (i.e. plotting)
   f. While plotting
      1) Insert new PCB in socket on shaker.
      2) Write PCB s/n and date on paper.
   g. When plotting done repeat starting at step 4a for next transducer until done.

5. Power down equipment.
   a. CAUTION:Turn power Amp level down first.
   b. Turn off all equipment.

NOTES: The above procedure was used to get DC-200 Hz Transfer Functions.
The Columbia 902H was the reference for near DC-5 kHz Transfer Functions.
We need DC-10 kHz flat response reference accelerometer.
At start and end of day, check Setra vs 902H and performed Setra 3 point cal.

III Format Of PCM Serial Data For F-16 Wing GVT -

Major Frame 347 2/9 times per second					Next Frame
Sync Word 1	Sync Word 2	Word 1	Words 2-40	Words 41-46	Sync Word 1
111110101111	011100110100	010010101101	101001100111	101010100110	111110101111

|--0.000060--|
seconds/word

/Subcommutation\

GAIN CODES		FRAME COUNT	TIME CODE IRIG - B 17 BIT BCD		
WORD #41	WORD #42	WORD #43 SECONDS .01 .1 SFID	WORD #44 HOURS Tens Unit	WORD #45 MINUTES Tens Unit	WORD #46 SECONDS Tens Unit
5 6 7 5	6 7 5 0		1 xx 9	3 xx 9	5 xx 8
101110111101	110111101000	CNTR	XX0100001001	X01100001001	X10100001000
25 17 9 1	xx xx xx 33	000000000000	XX0100001001	X01100001001	X10100001000
26 18 10 2	xx xx xx 34	000000000001			
27 19 11 3	xx xx xx 35	000000000010			
28 20 12 4	xx xx xx 36	000000000011			
29 21 13 5	xx xx xx 37	000000000100			
30 22 14 6	xx xx xx 38	000000000101			
31 23 15 7	xx xx xx 39	000000000110			
32 24 16 8	xx xx xx 40	000000000111			
25 17 9 1	xx xx xx 33	000000000000	XX0100001001	X01100001001	X10100001000
AMP # GAINS					

NOTES:
(200 KBITS/SEC)(1WORD/ 12 BITS)(1 FRAME/ 48 WORDS) = 347 2/9 MAJOR FRAMES/SECOND
DMM encoding-12 bits per word straight binary
xx means not used or don't care

Binary Output MSB		LSB	Decimal Value	Gain
0	0	0	0	+60 DB
0	0	1	1	+50 DB
0	1	0	2	+40 DB
0	1	1	3	+30 DB
1	0	0	4	+20 DB
1	0	1	5	+10 DB
1	1	0	6	0 DB
1	1	1	7	-10 DB

Binary Output: +5VDC = false = 0
Ground = true = 1

IV Assignment Of PCM Word Numbers To Transducers -

WORD	PCB S/N	WORD	PCB S/N	WORD	PCB S/N
1	841	16	1174	31	1212
2	970	17	1170	32	867
3	1089	18	1193	33	1215
4	936	19	1258	34	1234
5	857	20	1210	35	1208
6	1016	21	1237	36	1218
7	1101	22	1243	37	818
8	1134	23	1153		
9	1091	24	1139		
10	1076	25	1219		
11	1063	26	1213		
12	907	27	1247		
13	889	28	1255		
14	892	29	1242		
15	546	30	1249		

WORD	Transducer Description
38	Force Gage
39	Termo Couple or Unfiltered Setra S/N 120511
40	Setra S/N 120511

V Log Of F-16 Wing Test Recorded Calibrations -

DATE	REC#	TAPE-TRACK#	TIME (min:sec)	COMENTS
5/1/87	Voice 1	A-1	0:24 0:50	3pt Static Cal,+1g,0g,-1g,0g,+1g WD40-20dB-Filtered,WD39-20dB-No Filter
5/1/87	Voice 2	A-1	0:52 1:12	Word 1 thru Word 15 Sine calibration PCB accelerometers f=25 Hz WD39-Setra-No Filter 96.1mv WD40-Setra 101.5 Amp40=490mv
5/1/87	Voice 3	A-1	0:46 8:10	RN WD1-15 G=0dB WD39,40 G=20dB
5/6/87	Voice 5	A-1	0:24 0:51	3pt Static Cal,+1g,0g,-1g,0g,+1g WD39-20dB-No Filter,WD40-20dB-Filtered
5/6/87	Voice 6	A-1	0:23 1:10	Word16 thru Word30 Sine Calibration PCB accelerometers G=10dB f=25Hz WD39-Setra-NoFilter94mv-G=20dB WD40-Setra-filter-100mv-G=20dB, DC coupled
5/6/87	Voice 7	A-1	0:30 7:30	RN on Shaker,autorange for 0dB on WD16-30(fixed 30 @0dB) WD39,40 G=20dB
5/7/87	Voice 8	A-1	0:26 0:57	3point cal,+1g,0g,-1g,0g,+1g WD40-20dB-filtered,WD39-20dB-No filter
5/7/87	Voice 9	A-1	1:01 1:30	Word31 thru Word37 Sine Calibration PCB accelerometers G=0dB f=25HZ WD39-Setra-No Filter-G=20dB WD40-Setra-Filtered-G=20dB
5/7/87	Voice 10	A-1	0:41 9:00	RN on shaker-Autorange to 0db WD31 fixed 0dB WD32-37
8/7/87	Voice 58	C-5	0:28 1:07	3pt Cal +1g-2478 counts 0g-2059,-1g-1609,0g-2049,+1g-2478 WD40-Setra
8/7/87	Voice 59	C-5	0:20 4:00	37 PCB cals RN in all channels Post Cal, Setra Ref. WD40

Notes: WD=Word,RN=Random Noise,Hz=Hz,G=Gain,Setra=SN120511

VI PCB Accelerometer Random Noise Calibration Transfer Function Averages - (WORD X/WORD 40) in COUNTS/G

FREQ		0.15000000E+02	0.20000000E+02	0.25000000E+02	0.30000000E+02	0.35000000E+02
WORD-REC						
1	3	0.48584088E+03	0.97406268E+03	0.97212256E+03	0.97144336E+03	0.48704840E+03
2	3	0.42188776E+03	0.84421191E+03	0.84117957E+03	0.83965479E+03	0.42071271E+03
3	3	0.42755902E+03	0.85547913E+03	0.85195947E+03	0.85005499E+03	0.42588193E+03
4	3	0.49362149E+03	0.98787793E+03	0.98333936E+03	0.98017834E+03	0.49071069E+03
5	3	0.45662994E+03	0.91430713E+03	0.91161603E+03	0.91076941E+03	0.45681586E+03
6	3	0.44934000E+03	0.89784210E+03	0.89091504E+03	0.88853674E+03	0.44441992E+03
7	3	0.45776059E+03	0.91515869E+03	0.91072198E+03	0.90805762E+03	0.45483771E+03
8	3	0.45315448E+03	0.90637482E+03	0.90083630E+03	0.89559558E+03	0.44718832E+03
9	3	0.44283038E+03	0.88366028E+03	0.87849786E+03	0.87589423E+03	0.43884418E+03
10	3	0.40352777E+03	0.80803656E+03	0.80569434E+03	0.80458142E+03	0.40335922E+03
11	3	0.47307999E+03	0.94681335E+03	0.94420490E+03	0.94341296E+03	0.47312482E+03
12	3	0.47520093E+03	0.94801648E+03	0.94355579E+03	0.94162585E+03	0.47232855E+03
13	3	0.45780127E+03	0.91566278E+03	0.91160413E+03	0.90947833E+03	0.45562042E+03
14	3	0.44024689E+03	0.87931085E+03	0.87588739E+03	0.87461145E+03	0.43859805E+03
15	3	0.47887411E+03	0.95942755E+03	0.95734094E+03	0.95609875E+03	0.47928824E+03
16	7	0.42057535E+03	0.84125635E+03	0.83570245E+03	0.83362610E+03	0.41717789E+03
17	7	0.45578653E+03	0.91188037E+03	0.90665247E+03	0.90527258E+03	0.45335431E+03
18	7	0.42331085E+03	0.84711523E+03	0.84390314E+03	0.84304218E+03	0.42244800E+03
19	7	0.40184567E+03	0.80466577E+03	0.80129608E+03	0.80136365E+03	0.40203165E+03
20	7	0.45107162E+03	0.90254309E+03	0.89802734E+03	0.89589728E+03	0.44849579E+03
21	7	0.45905258E+03	0.91802020E+03	0.91211829E+03	0.90995538E+03	0.45533575E+03
22	7	0.40978448E+03	0.81932031E+03	0.81491077E+03	0.81261688E+03	0.40677170E+03
23	7	0.42145844E+03	0.84434033E+03	0.84107452E+03	0.83833624E+03	0.41923950E+03
24	7	0.44666431E+03	0.89418439E+03	0.89111963E+03	0.88908203E+03	0.44526392E+03
25	7	0.42628452E+03	0.85110321E+03	0.84464630E+03	0.83969745E+03	0.41946289E+03
26	7	0.44955859E+03	0.90083997E+03	0.89703241E+03	0.89475391E+03	0.44769916E+03
27	7	0.45205963E+03	0.90462952E+03	0.90069464E+03	0.89811798E+03	0.44975400E+03
28	7	0.45235907E+03	0.88878674E+03	0.87324786E+03	0.87683777E+03	0.43703262E+03
29	7	0.44542999E+03	0.89083118E+03	0.88638507E+03	0.88377502E+03	0.44252725E+03
30	7	0.46353033E+03	0.92605530E+03	0.92044446E+03	0.91683270E+03	0.45912616E+03
31	10	0.47250894E+03	0.94342548E+03	0.93933118E+03	0.93619495E+03	0.46846695E+03
32	10	0.47174878E+03	0.94293896E+03	0.93883997E+03	0.93464905E+03	0.46788843E+03
33	10	0.45768671E+03	0.91325049E+03	0.90722949E+03	0.90157324E+03	0.45040781E+03
34	10	0.41576361E+03	0.83168640E+03	0.82808270E+03	0.82428967E+03	0.41245526E+03
35	10	0.45467050E+03	0.91157489E+03	0.91031494E+03	0.90931122E+03	0.45576987E+03
36	10	0.45893573E+03	0.91676672E+03	0.91256427E+03	0.90925421E+03	0.45526929E+03
37	10	0.45763931E+03	0.91630695E+03	0.91260919E+03	0.90858966E+03	0.45539331E+03

NOTE: Table gives average value of transfer function between Word x and 40. The average is in terms of counts/g. The average is computed over a 5 Hz bandwidth centered on the given frequencies.

VII Input Data For Program BASCAL.BA -

```
114ZT,1,841,1.23,972.1,0,2496.0,1668.0,2075.6,2095.8,-10
113ZT,2,970,1.02,841.2,0,2490.0,1769.0,2124.7,2139.7,-10
93ZT,3,1089,1.07,852.0,0,2546.0,1819.0,2176.6,2195.5,-10
73ZT,4,936,1.22,983.3,0,2472.0,1639.0,2049.2,2070.1,-10
53ZT,5,857,1.17,911.6,0,2439.0,1663.0,2044.7,2062.7,-10
13ZT,6,1016,1.08,890.9,0,2386.0,1611.0,1990.3,2008.2,-10
12ZT,7,1101,1.16,910.7,0,2435.0,1663.0,2043.3,2061.3,-10
11ZT,8,1134,1.14,900.8,0,2463.0,1704.0,2078.2,2095.3,-10
61YT,9,1091,1.09,878.5,0,2017.0,1269.0,1635.8,1656.8,-10
61XT,10,1076,1.02,805.7,0,2369.0,1689.0,2024.0,2038.1,-10
61ZT,11,1063,1.19,944.2,0,2440.0,1642.0,2034.0,2053.3,-10
111YT,12,907,1.14,943.6,0,2563.0,1752.0,2150.0,2168.3,-10
111ZT,13,889,1.11,911.6,0,2487.0,1705.0,2091.1,2108.9,-10
61YB,14,892,1.07,875.9,0,2426.0,1673.0,2043.4,2060.2,-10
111YB,15,546,1.18,957.3,0,2460.0,1646.0,2046.0,2065.8,-10
107ZT,16,1174,1.04,835.7,0,2387.0,1722.0,2049.9,2063.2,-10
97ZT,17,1170,1.13,906.7,0,2299.0,1579.0,1933.5,1950.0,-10
17ZT,18,1193,1.05,843.9,0,2402.0,1734.0,2062.7,2076.0,-10
16ZT,19,1258,1.04,801.3,0,2589.0,1949.0,2264.3,2275.4,-10
86ZT,20,1210,1.14,898.0,0,2409.0,1690.0,2044.1,2059.7,-10
106ZT,21,1237,1.12,912.1,0,2418.0,1693.0,2049.4,2065.2,-10
116ZT,22,1243,1.02,814.9,0,2371.0,1729.0,2045.5,2057.9,-10
115ZT,23,1153,1.06,841.1,0,3086.0,1015.0,2036.4,2163.1,0
95ZT,24,1139,1.13,891.1,0,2398.0,1696.0,2042.3,2057.0,-10
75ZT,25,1219,1.06,844.6,0,2367.0,1706.0,2032.1,2045.4,-10
15ZT,26,1213,1.12,897.0,0,2371.0,1656.0,2008.1,2023.7,-10
14ZT,27,1247,1.13,900.7,0,2427.0,1711.0,2063.3,2078.6,-10
54ZT,28,1255,1.11,873.2,0,3223.0,2387.0,2815.7,2826.9,-10
74ZT,29,1242,1.11,886.4,0,2406.0,1701.0,2048.0,2063.0,-10
94ZT,30,1249,1.10,920.4,0,2407.0,1679.0,2037.7,2053.7,-10
117ZT,31,1212,1.18,939.3,0,3215.0,899.0,2043.7,2200.4,0
118ZT,32,867,1.13,938.8,0,3085.0,783.0,1919.7,2084.0,0
108ZT,33,1215,1.14,907.2,0,3154.0,906.0,2015.9,2165.6,0
98ZT,34,1234,1.04,828.1,0,3140.0,1102.0,2105.4,2224.5,0
18ZT,35,1208,1.17,910.3,0,3184.0,939.0,2044.86,2192.9,0
119ZT,36,1218,1.15,912.6,0,3091.0,843.0,1951.8,2106.4,0
19ZT,37,818,1.17,912.6,0,3152.0,903.0,2012.9,2163.3,0
SET1,41,120511,,,,7.043,4.298,5.645,5.723,
SET2,42,120511,,,,6.916,4.420,5.648,5.715,
SET3,43,120511,,,,6.806,4.335,5.557,5.624,
```

NOTES: The above data was stored in a file called PCBCAL.DO. The data is position dependent separated by commas as follows:

location,ID#,Serial Number,Oct 86 V/g lab cal,random noise counts/g at f=25 Hz, random noise gain,sine record max,sine record min,sine record mean, sine record rms,sine record gain

VIII Output From Program BASCAL.BA On M-100 -

METHOD LOCATION	WORD	SER NO.	LAB OCT86	Random Noise g/count@0db	Random Noise V/g	Random Noise %err	SineMaxMin V/g	SineMaxMin %err	SineMeanrms V/g	SineMeanrms %err
114ZT	1	841	1.23	1.029E-03	1.1869	-3.4	1.16	-5.2	1.19	-3.1
113ZT	2	970	1.02	1.189E-03	1.0271	0.7	1.01	-0.5	1.04	1.7
93ZT	3	1089	1.07	1.174E-03	1.0403	-2.7	1.02	-4.3	1.18	10.2
73ZT	4	936	1.22	1.017E-03	1.2006	-1.5	1.17	-3.9	1.20	-1.3
53ZT	5	857	1.17	1.097E-03	1.1131	-4.8	1.09	-6.6	1.11	-4.6
13ZT	6	1016	1.08	1.122E-03	1.0878	0.7	1.09	0.9	1.10	1.6
12ZT	7	1101	1.16	1.098E-03	1.1120	-4.0	1.09	-6.3	1.11	-3.8
11ZT	8	1134	1.14	1.110E-03	1.0999	-3.4	1.07	-6.2	1.10	-3.8
61YT	9	1091	1.09	1.138E-03	1.0726	-1.5	1.05	-3.4	1.08	-1.0
61XT	10	1076	1.02	1.241E-03	0.9838	-3.5	0.96	-6.1	0.98	-3.7
61ZT	11	1063	1.19	1.059E-03	1.1529	-3.0	1.12	-5.6	1.15	-3.1
111YT	12	907	1.14	1.060E-03	1.1521	1.1	1.14	0.1	1.15	1.1
111ZT	13	889	1.11	1.097E-03	1.1131	0.3	1.10	-0.8	1.12	1.0
61YB	14	892	1.07	1.142E-03	1.0695	0.0	1.06	-0.9	1.08	0.6
111YB	15	546	1.18	1.045E-03	1.1689	-0.8	1.14	-2.9	1.17	-0.7
107ZT	16	1174	1.04	1.197E-03	1.0204	-1.8	1.03	-1.0	1.04	-0.4
97ZT	17	1170	1.13	1.103E-03	1.1071	-1.9	1.11	-1.3	1.12	-0.8
17ZT	18	1193	1.05	1.185E-03	1.0304	-1.8	1.03	-1.5	1.04	-1.0
16ZT	19	1258	1.04	1.248E-03	0.9784	-5.8	0.99	-4.7	0.99	-4.4
86ZT	20	1210	1.14	1.114E-03	1.0965	-3.7	1.11	-2.3	1.12	-1.7
106ZT	21	1237	1.12	1.096E-03	1.1137	-0.5	1.12	0.1	1.13	0.7
116ZT	22	1243	1.02	1.227E-03	0.9950	-2.4	0.99	-2.5	1.00	-2.0
115ZT	23	1153	1.06	1.189E-03	1.0270	-3.0	1.01	-4.3	1.02	-3.6
95ZT	24	1139	1.13	1.122E-03	1.0880	-3.6	1.09	-3.8	1.09	-3.8
75ZT	25	1219	1.06	1.184E-03	1.0313	-2.6	1.02	-3.4	1.03	-2.7
15ZT	26	1213	1.12	1.115E-03	1.0952	-2.1	1.11	-1.1	1.11	-0.8
14ZT	27	1247	1.13	1.110E-03	1.0998	-2.6	1.11	-1.9	1.11	-1.3
54ZT	28	1255	1.11	1.145E-03	1.0662	-3.8	1.29	16.5*	1.11	0.2
74ZT	29	1242	1.11	1.128E-03	1.0823	-2.4	1.09	-1.6	1.10	-0.9
94ZT	30	1249	1.10	1.086E-03	1.1238	2.2	1.13	2.4	1.13	2.9
117ZT	31	1212	1.18	1.065E-03	1.1469	-2.7	1.14	-2.9	1.15	-2.4
118ZT	32	867	1.13	1.065E-03	1.1463	1.4	1.14	0.7	1.14	1.3
108ZT	33	1215	1.14	1.102E-03	1.1077	-2.7	1.11	-2.5	1.12	-2.0
98ZT	34	1234	1.04	1.208E-03	1.0111	-2.7	1.01	-3.1	1.01	-2.5
18ZT	35	1208	1.17	1.099E-03	1.1115	-4.9	1.11	-5.1	1.12	-4.4
119ZT	36	1218	1.15	1.096E-03	1.1143	-3.0	1.11	-3.3	1.12	-2.7
19ZT	37	818	1.17	1.096E-03	1.1143	-4.7	1.11	-4.9	1.12	-4.3

NOTE: Location code keyed to wing location on Wing GVT test.
* = worst case percent error.
Laboratory OCT 86 Cals from Table I Method 4.
Percent errors computed with respect to OCT 86 calibration.

10 Figures -

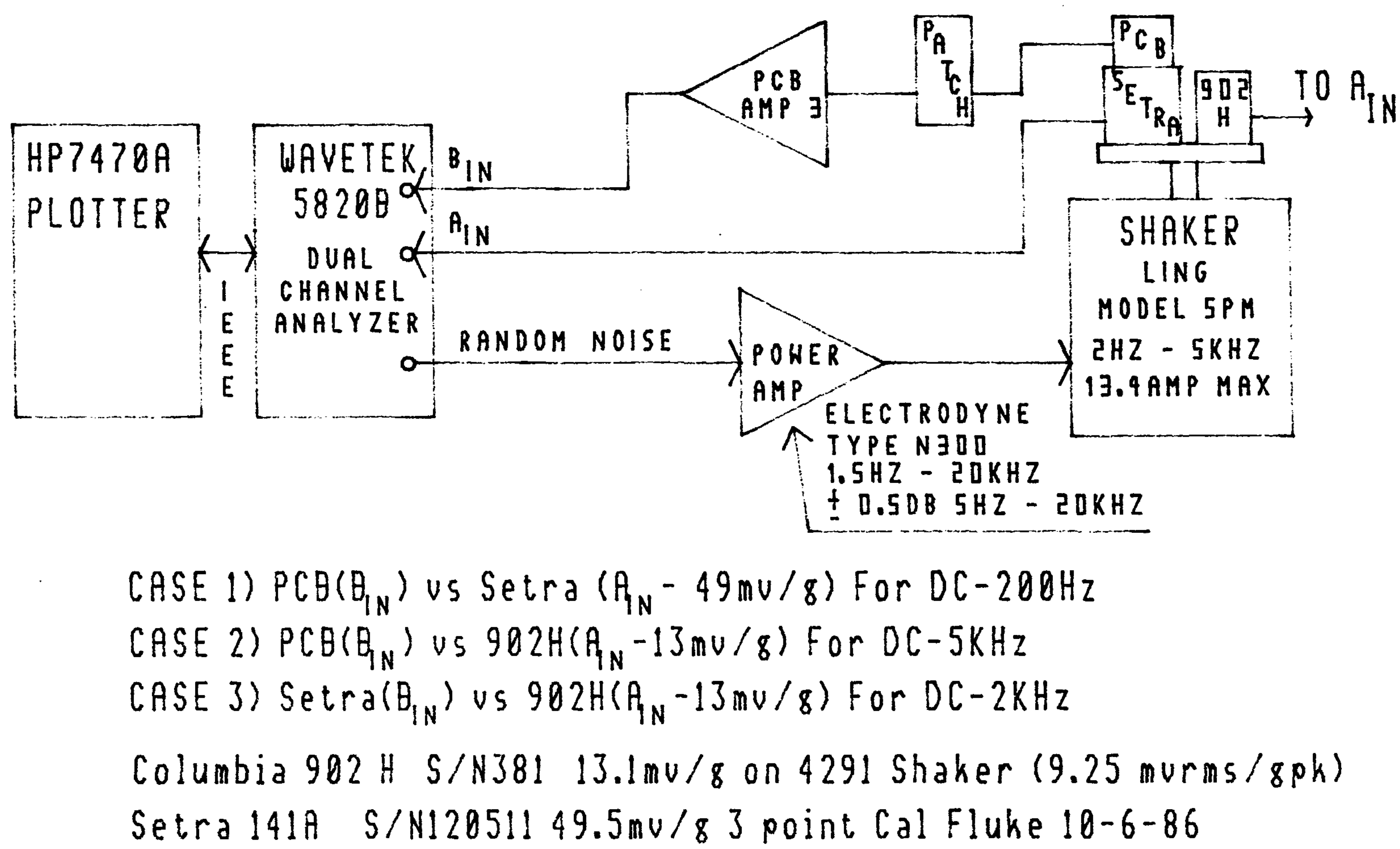


Figure 1. Laboratory Equipment Setup for Transfer Function Measurement

SETUP For PCB no. 902H

CH. A SN: -26dBV

CH. B SN: 14dBV

SPAN: 0.000HZ -5.0000KHZ

N: 32. SPECT AVG

MEASUREMENT MODE: CROSS CHANNEL

WEIGHTING FN: HANNING

INTERNAL SAMPLING

FREE RUN

MODIFIERS: NONE

[V/R] A=1.3E-02 B=1.0E+00

TSG: NOISE [9.25 × 1.414 = 13 mV/g = 902H Sens]

Figure 2. Analyzer Setup for High Frequency Transfer Function Measurements

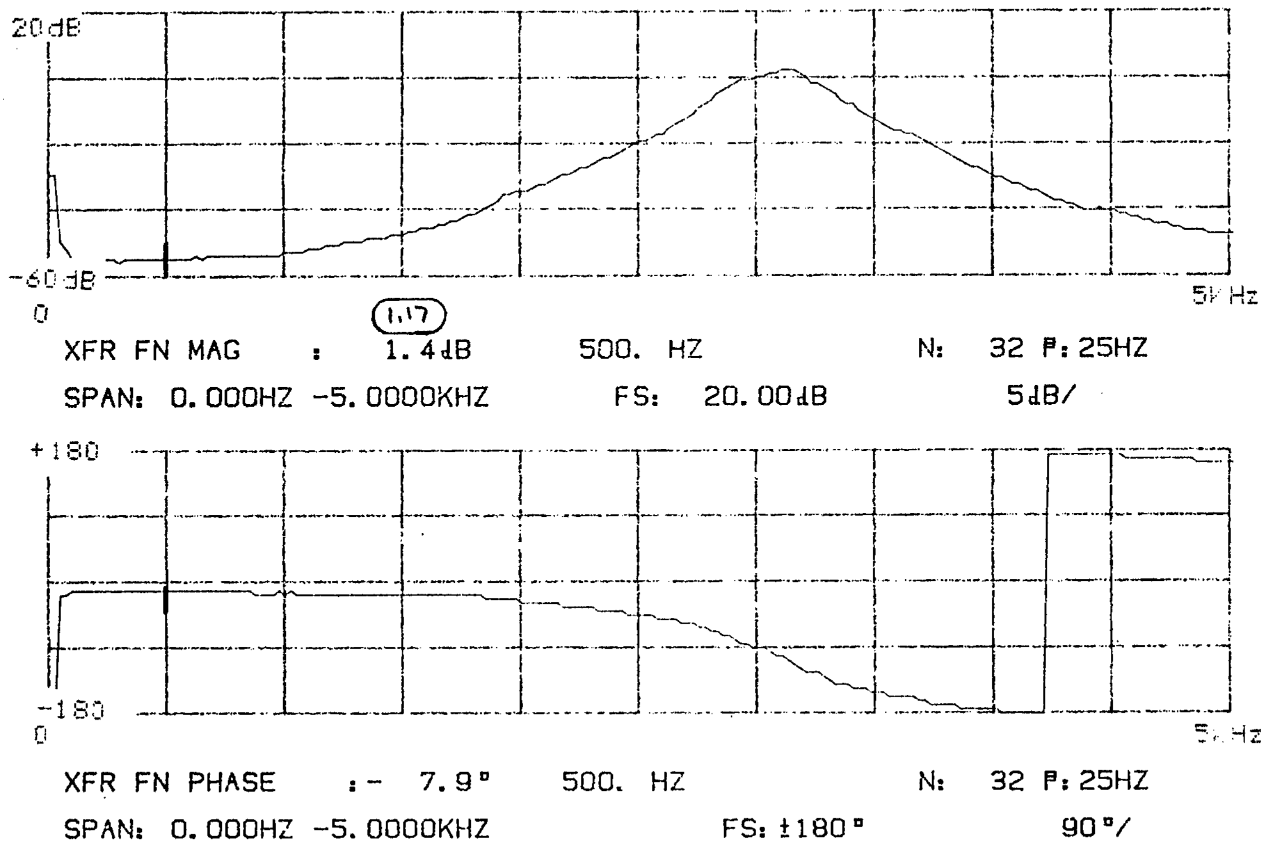
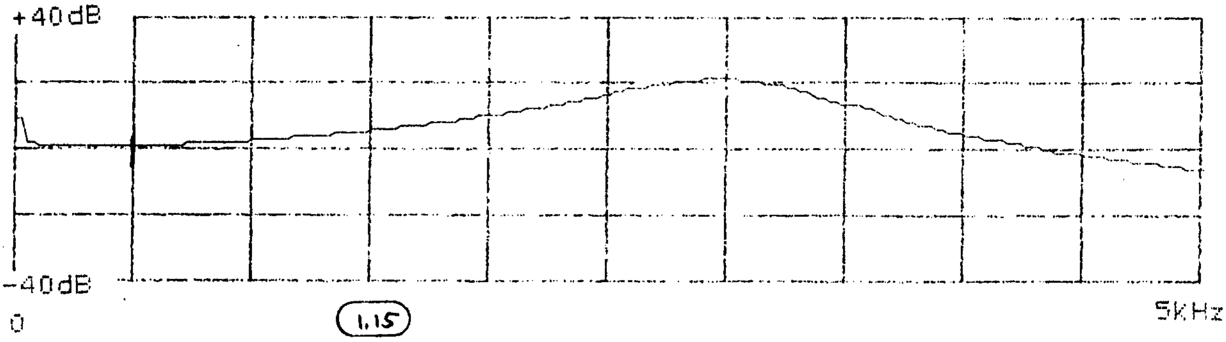


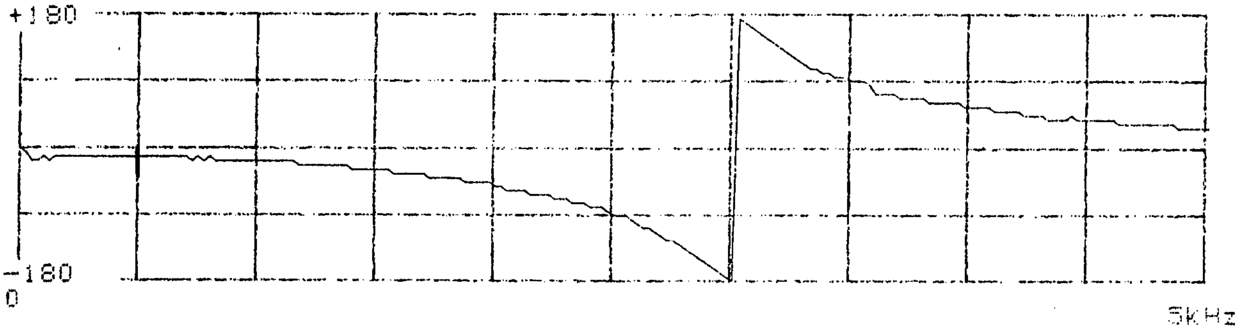
Figure 3. Transfer Function Amplitide and Phase for PCB SN857 vs Columbia 902H



(1.15)

XFR FN MAG : 1.2dB 500. HZ N: 32 P: 25HZ

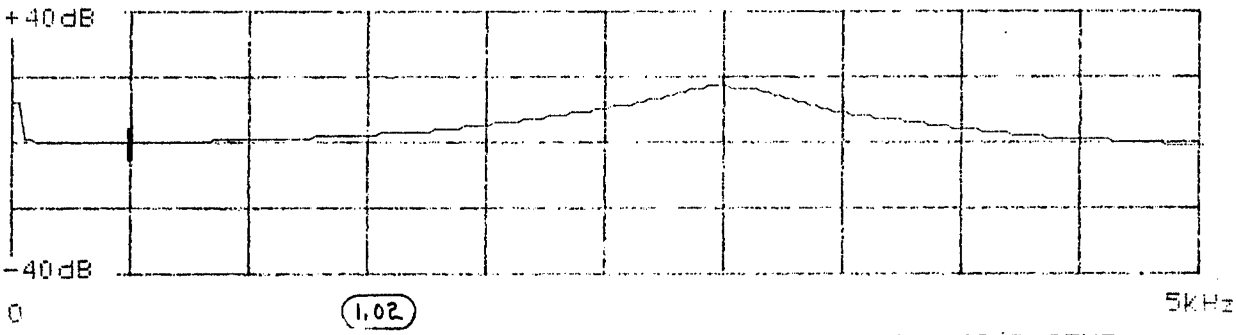
SPAN: 0.000HZ -5.0000KHZ FS: 40.00dB 20dB/



XFR FN PHASE : - 8.2° 500. HZ N: 32 P: 25HZ

SPAN: 0.000HZ -5.0000KHZ FS: ±180° 90°/

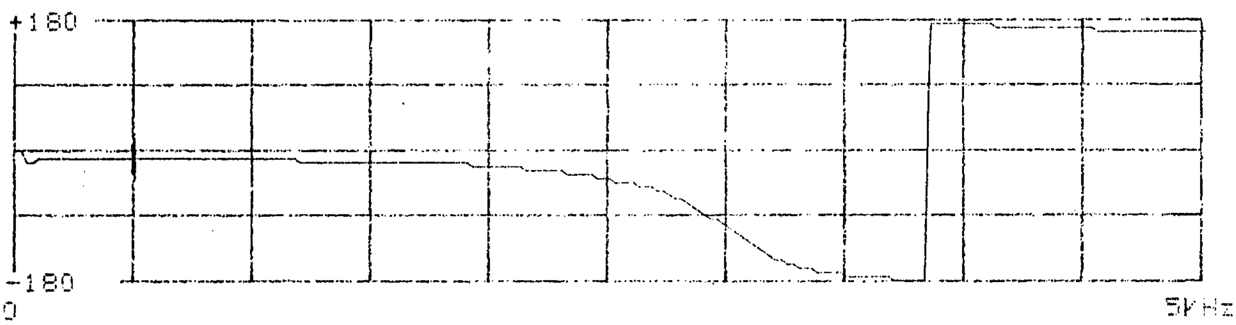
Figure 4. Transfer Function Amplitide and Phase for PCB SN1091 vs Columbia 902H



(1.02)

XFR FN MAG : 0.2dB 500. HZ N: 32 P: 25HZ

SPAN: 0.000HZ -5.0000KHZ FS: 40.00dB 20dB/



XFR FN PHASE : - 6.8° 500. HZ N: 32 P: 25HZ

SPAN: 0.000HZ -5.0000KHZ FS: ±180° 90°/

Figure 5. Transfer Function Amplitude and Phase for PCB SN1076 vs Columbia 902H

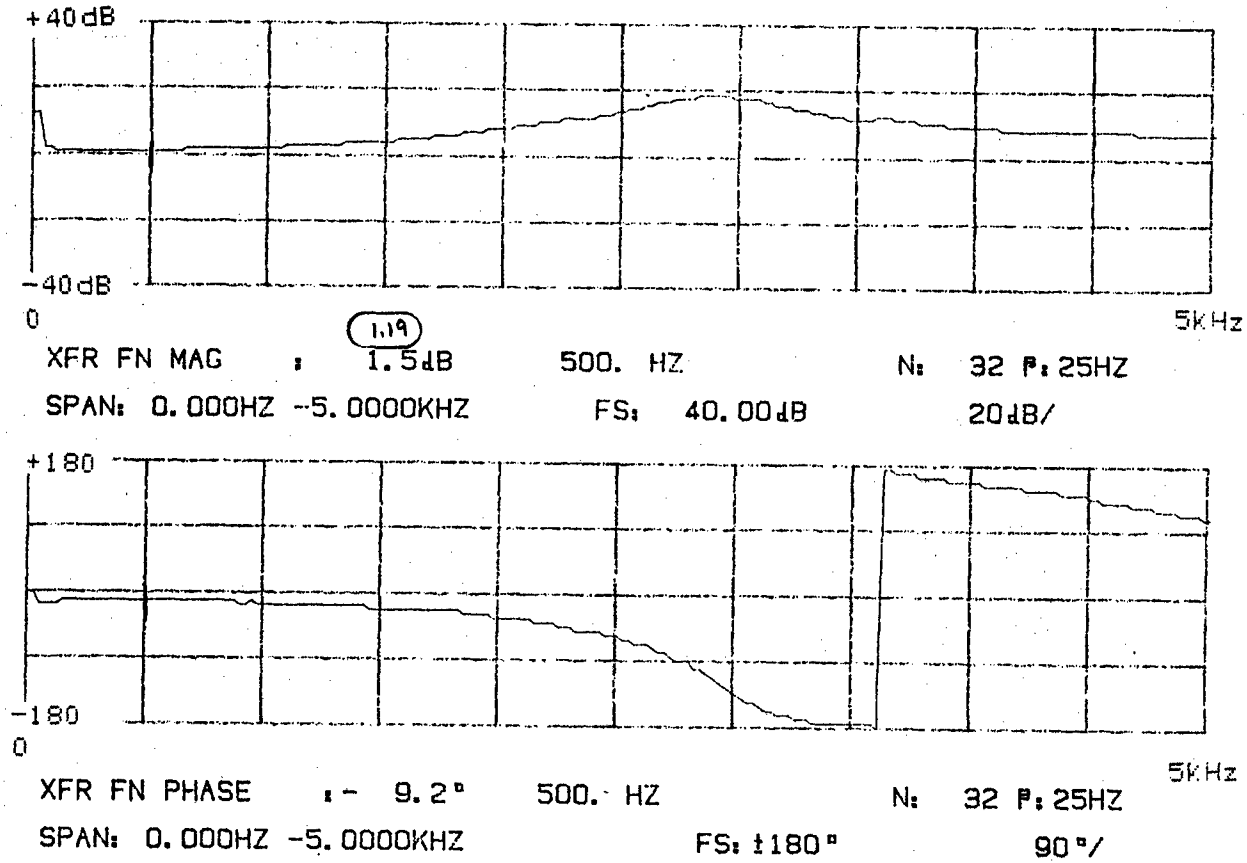


Figure 6. Transfer Function Amplitude and Phase for PCB SN1063 vs Columbia 902H

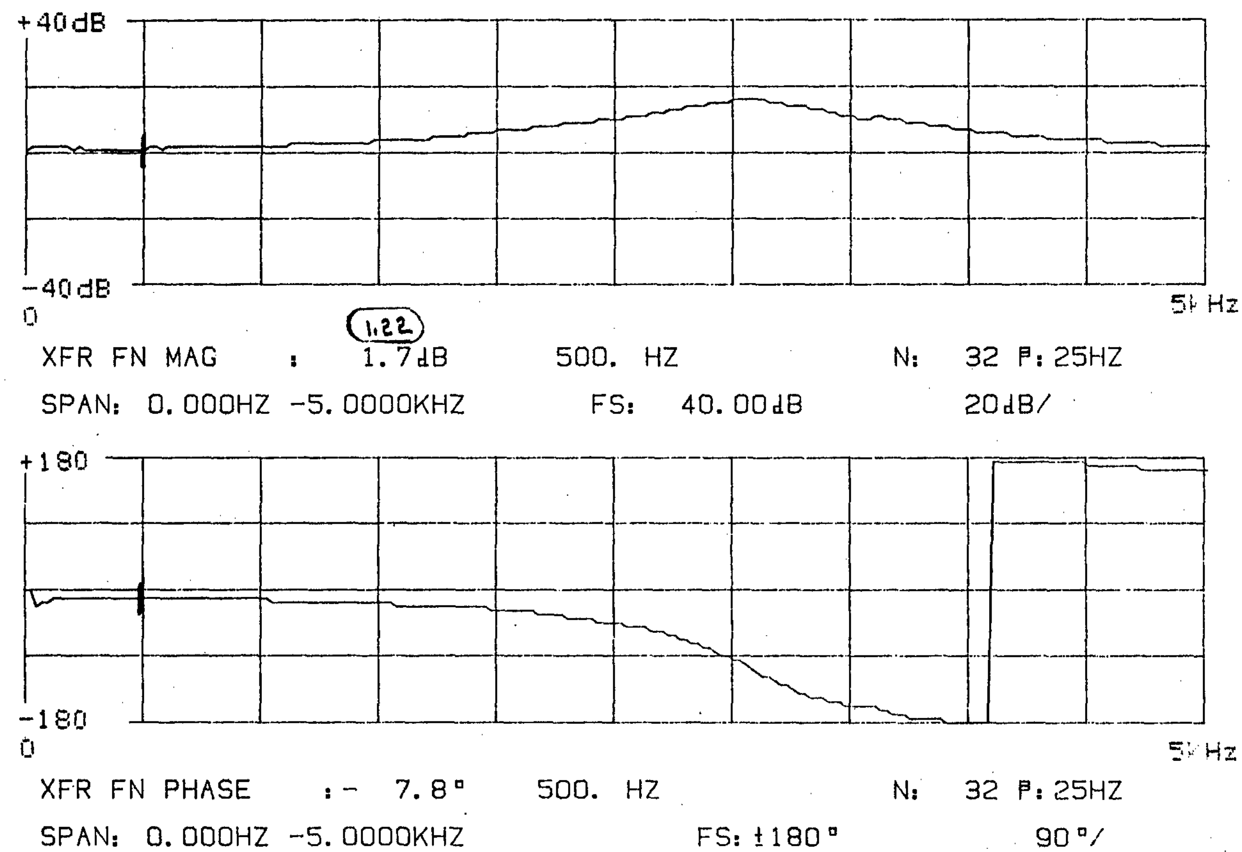


Figure 7. Transfer Function Amplitude and Phase for PCB SN936 vs Columbia 902H

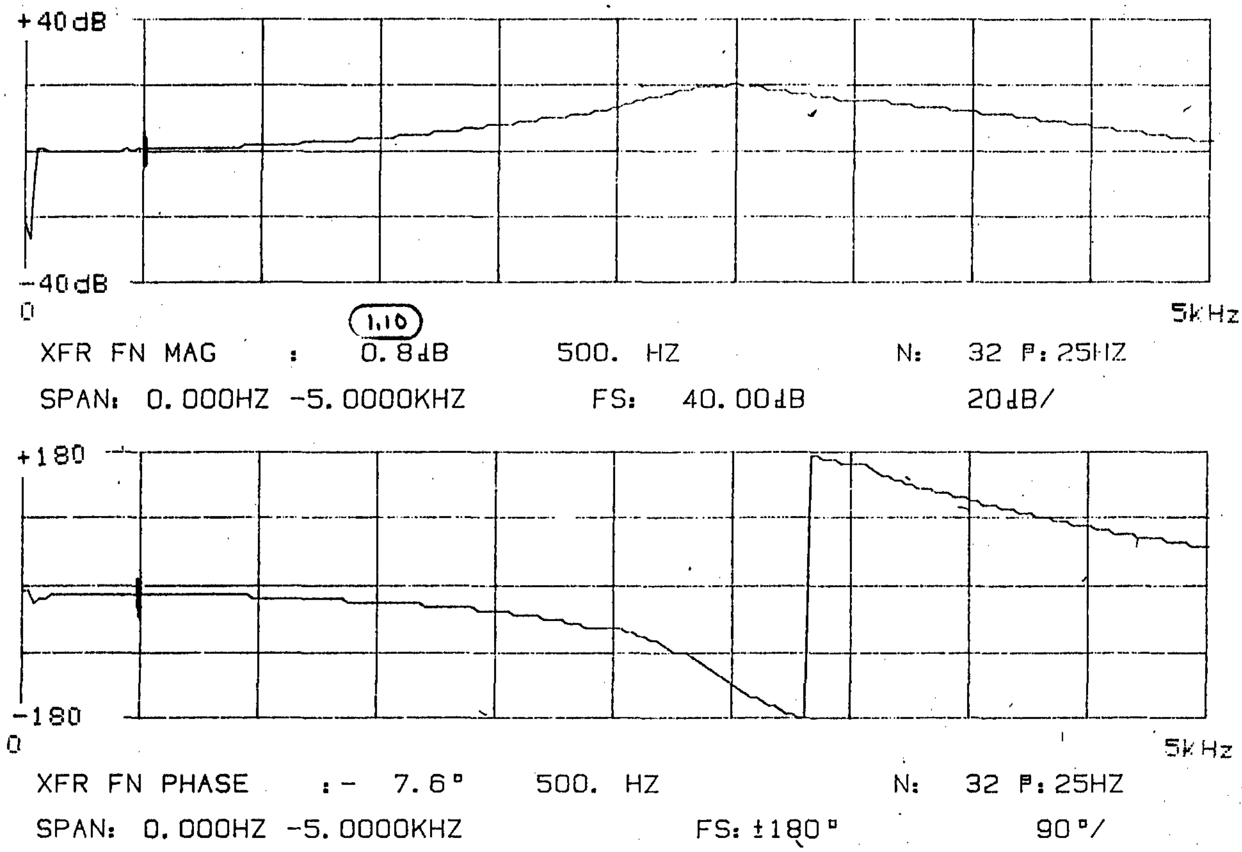


Figure 8. Transfer Function Amplitude and Phase for PCB SN1089 vs Columbia 902H

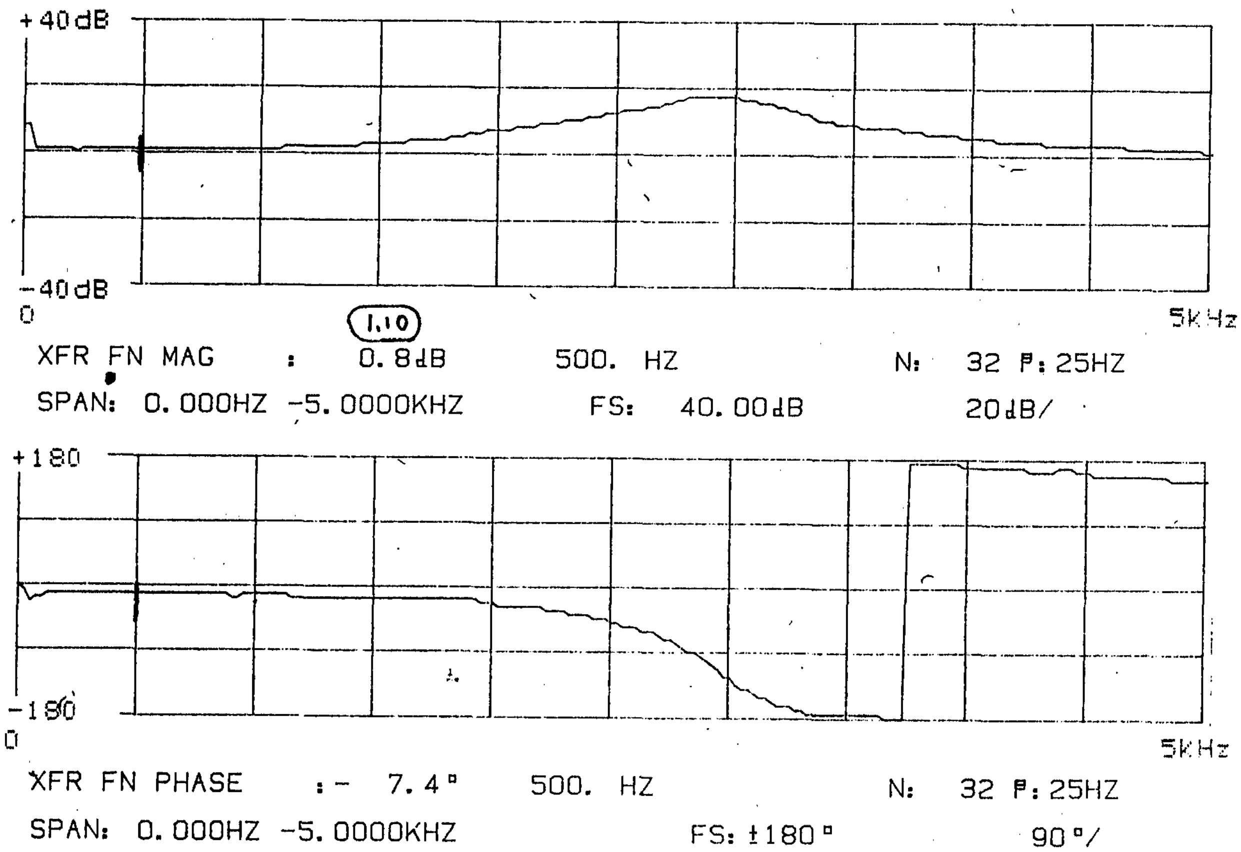


Figure 9. Transfer Function Amplitude and Phase for PCB SN1016 vs Columbia 902H

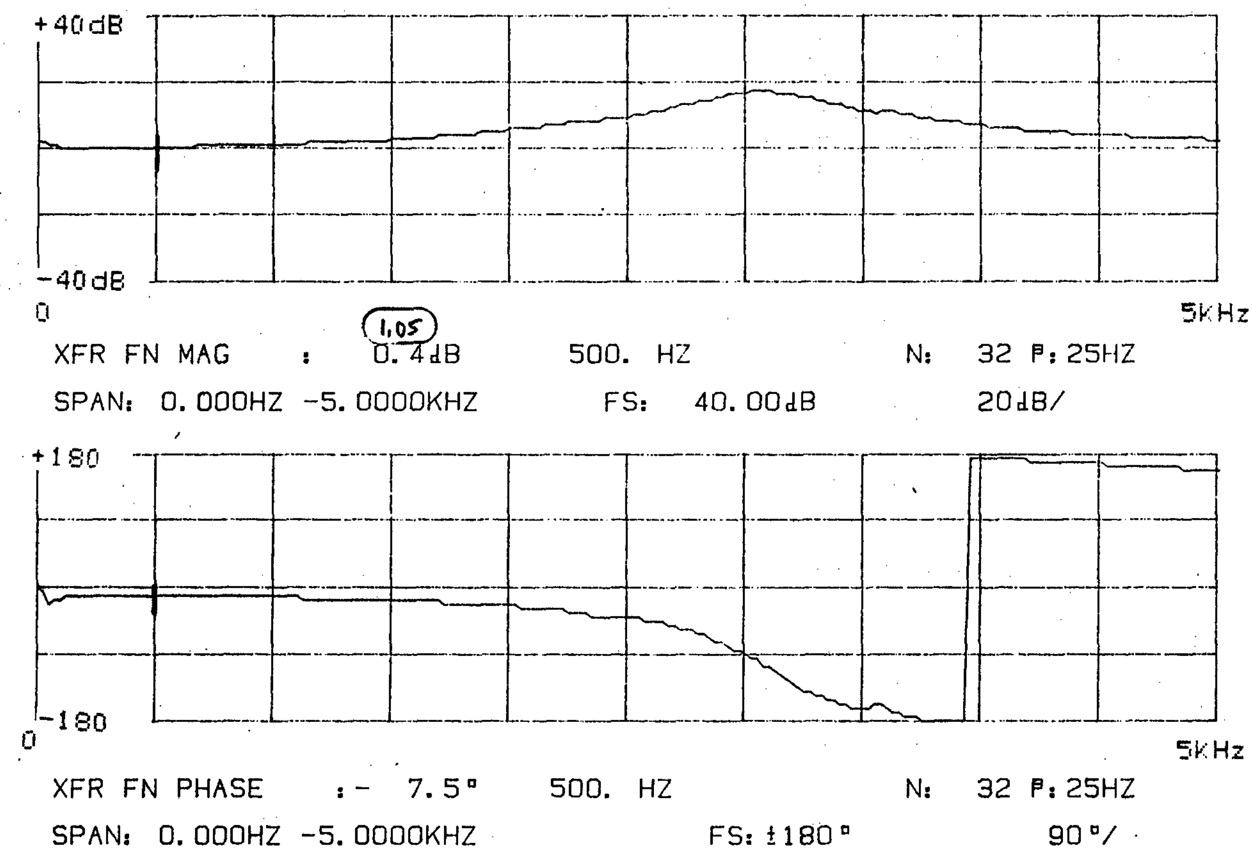


Figure 10. Transfer Function Amplitude and Phase for PCB SN970 vs Columbia 902H

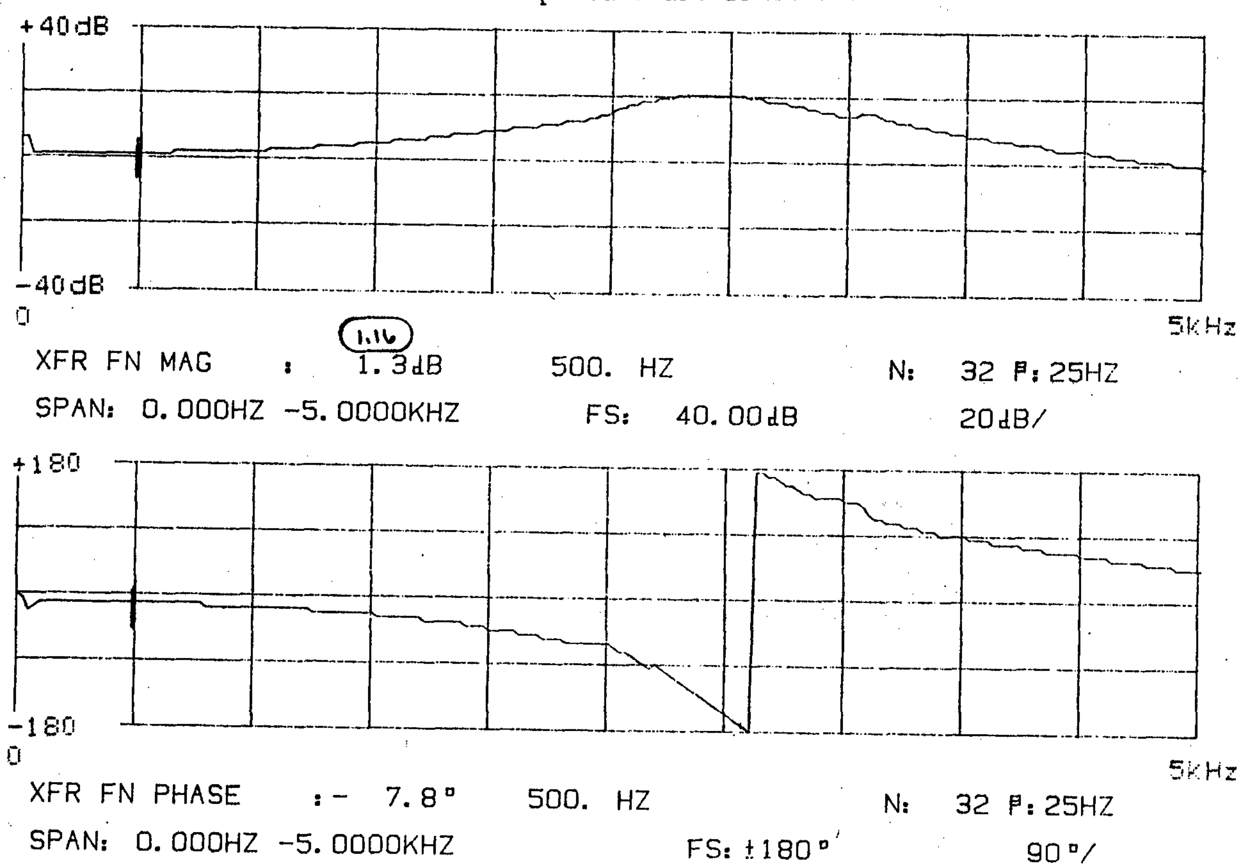


Figure 11. Transfer Function Amplitude and Phase for PCB SN1134 vs Columbia 902H

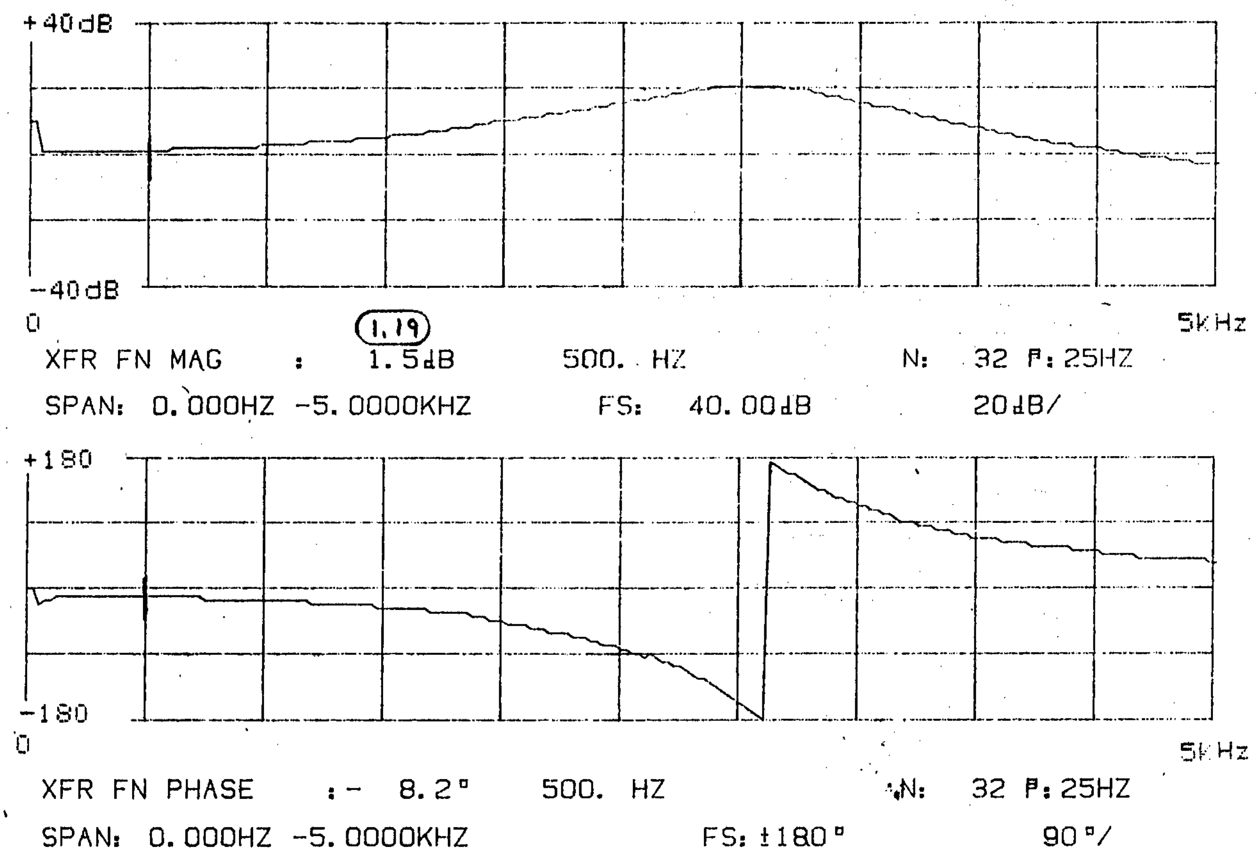


Figure 12. Transfer Function Amplitude and Phase for PCB SN1101 vs Columbia 902H

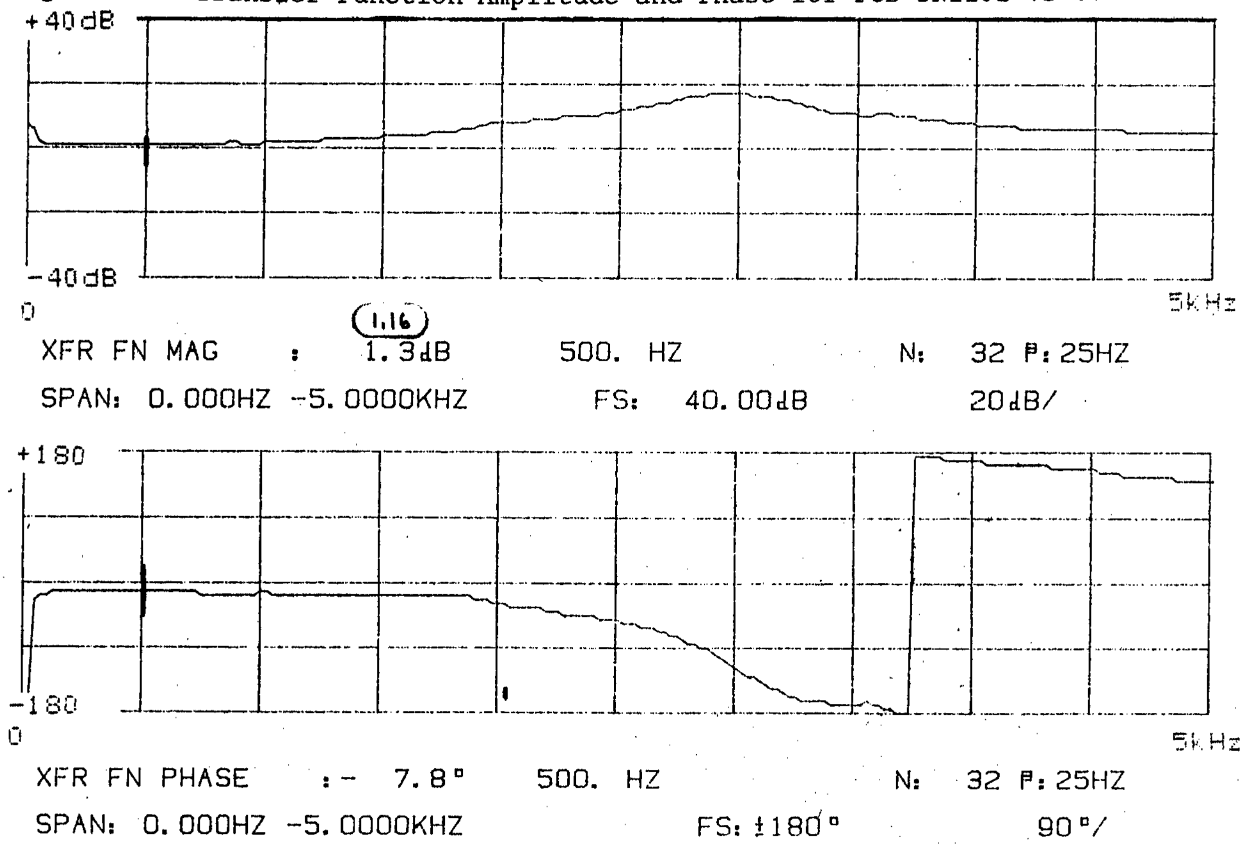


Figure 13. Transfer Function Amplitude and Phase for PCB SN889 vs Columbia 902H

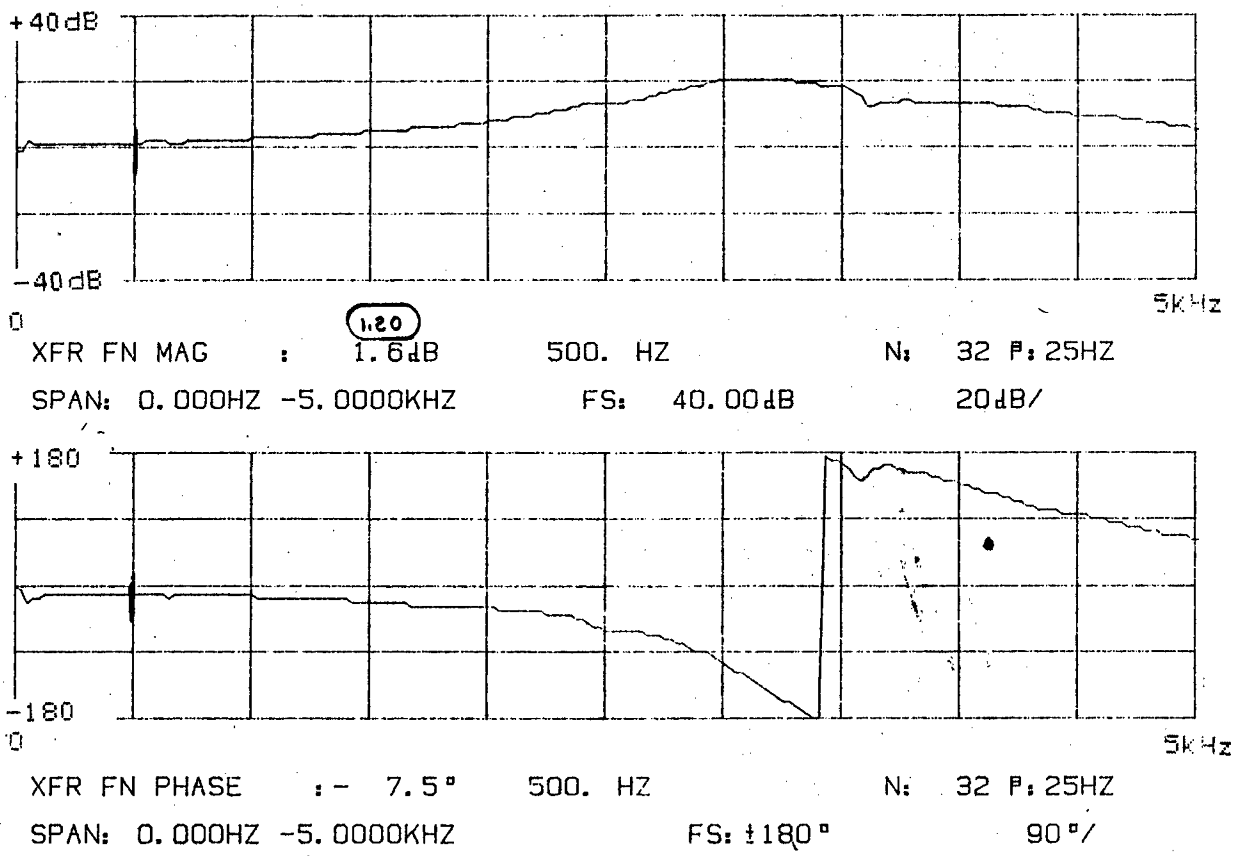


Figure 14. Transfer Function Amplitude and Phase for PCB SN907 vs Columbia 902H

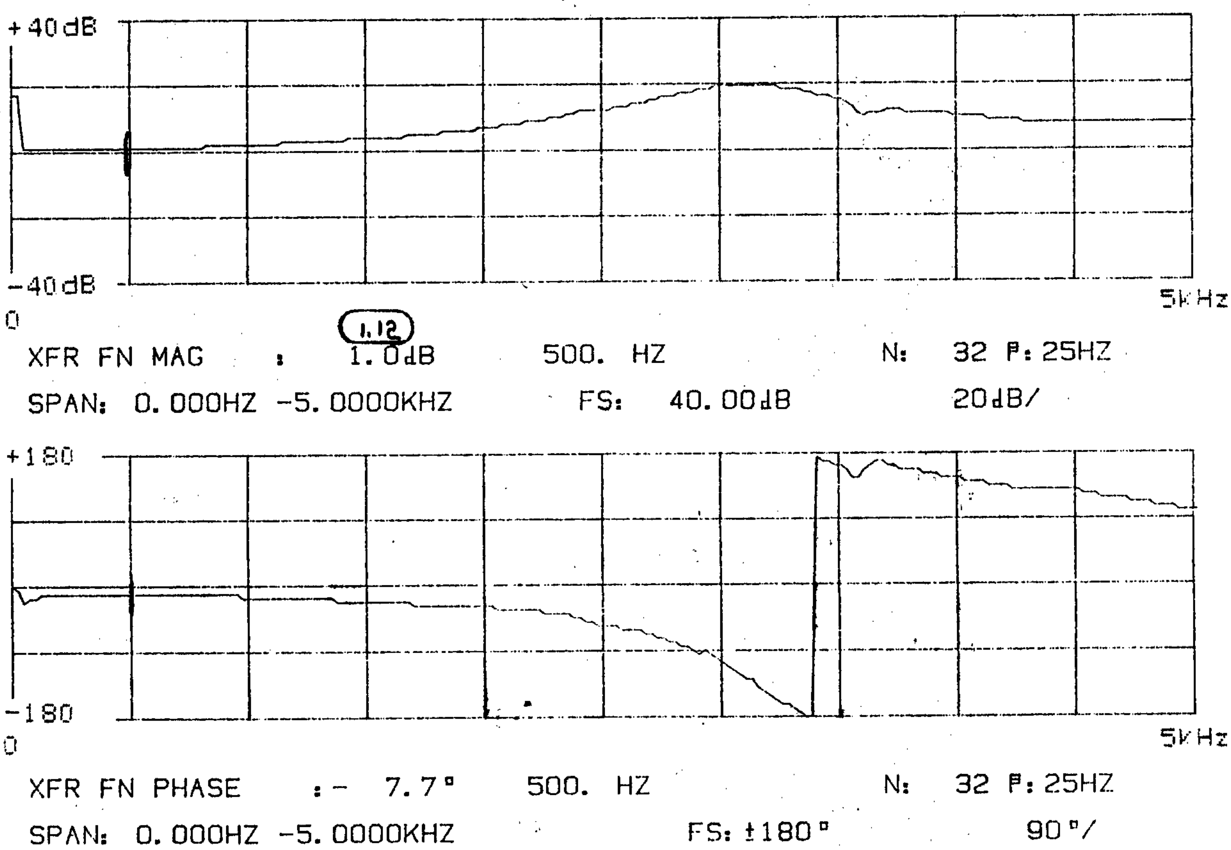


Figure 15. Transfer Function Amplitude and Phase for PCB SN892 vs Columbia 902H

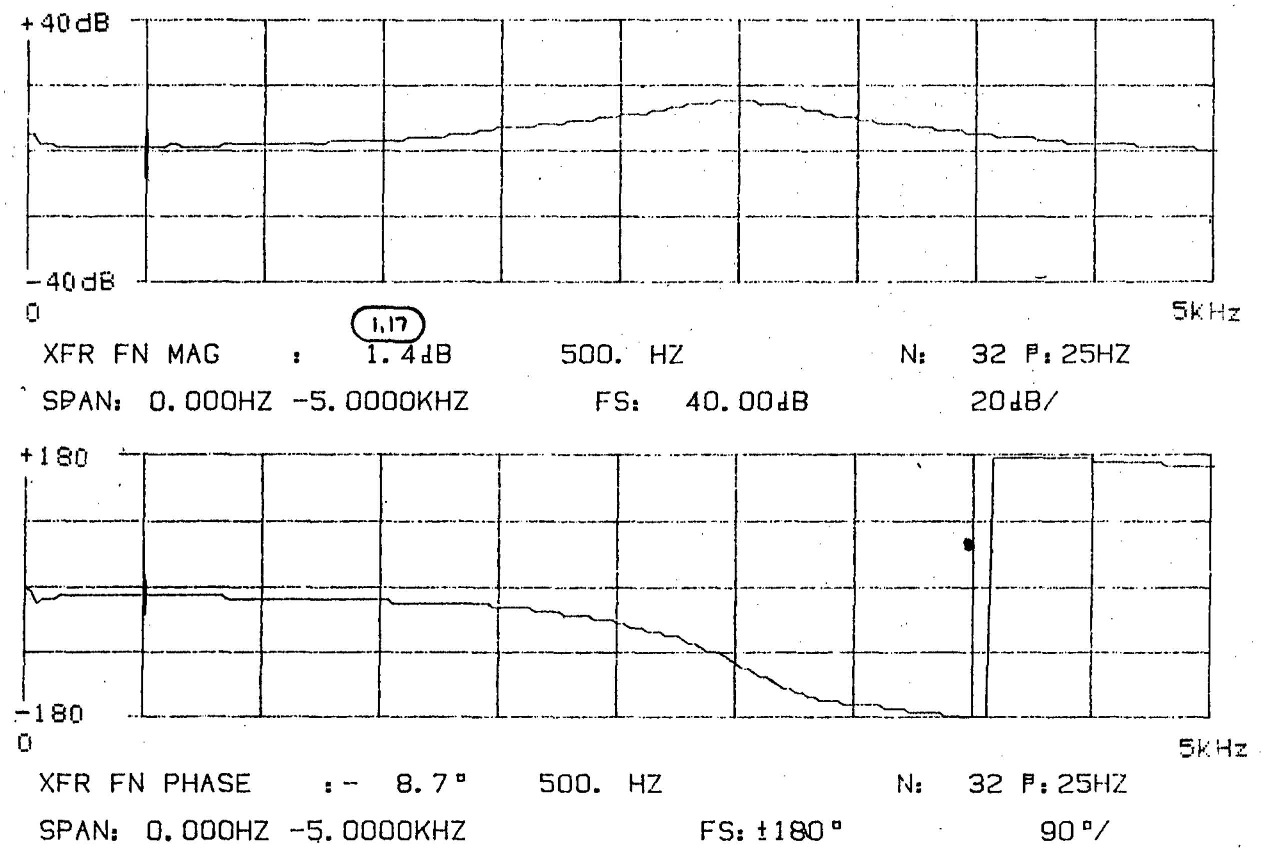


Figure 16. Transfer Function Amplitude and Phase for PCB SN841 vs Columbia 902H

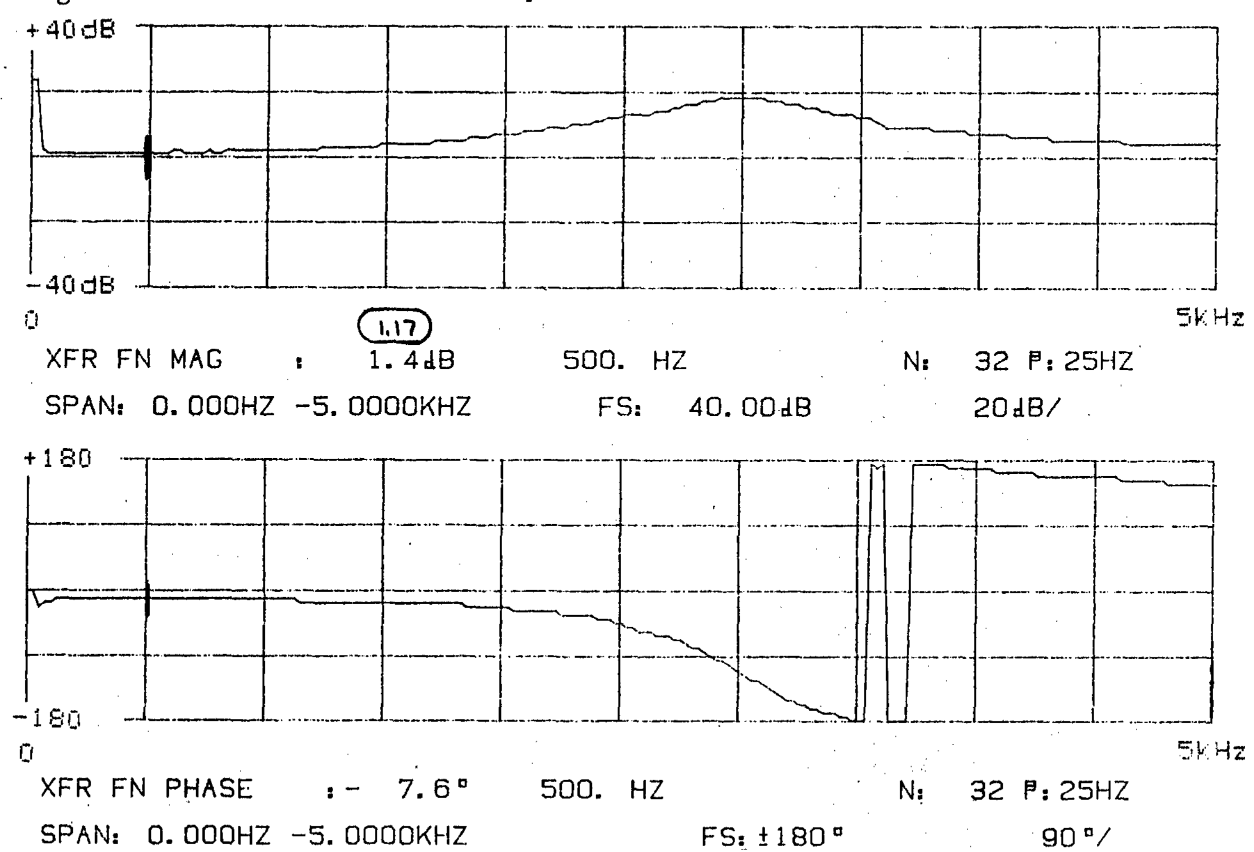


Figure 17. Transfer Function Amplitude and Phase for PCB SN546 vs Columbia 902H

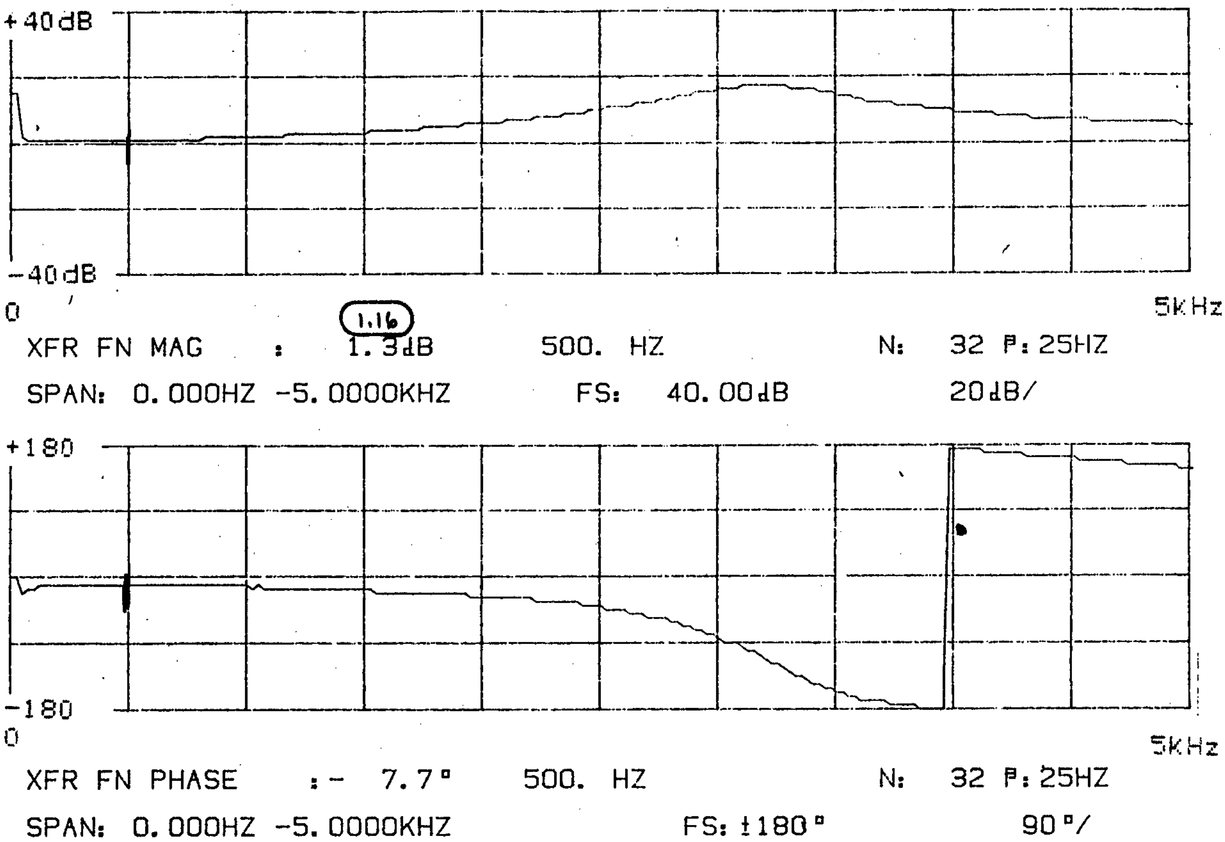


Figure 18. Transfer Function Amplitude and Phase for PCB SN818 vs Columbia 902H

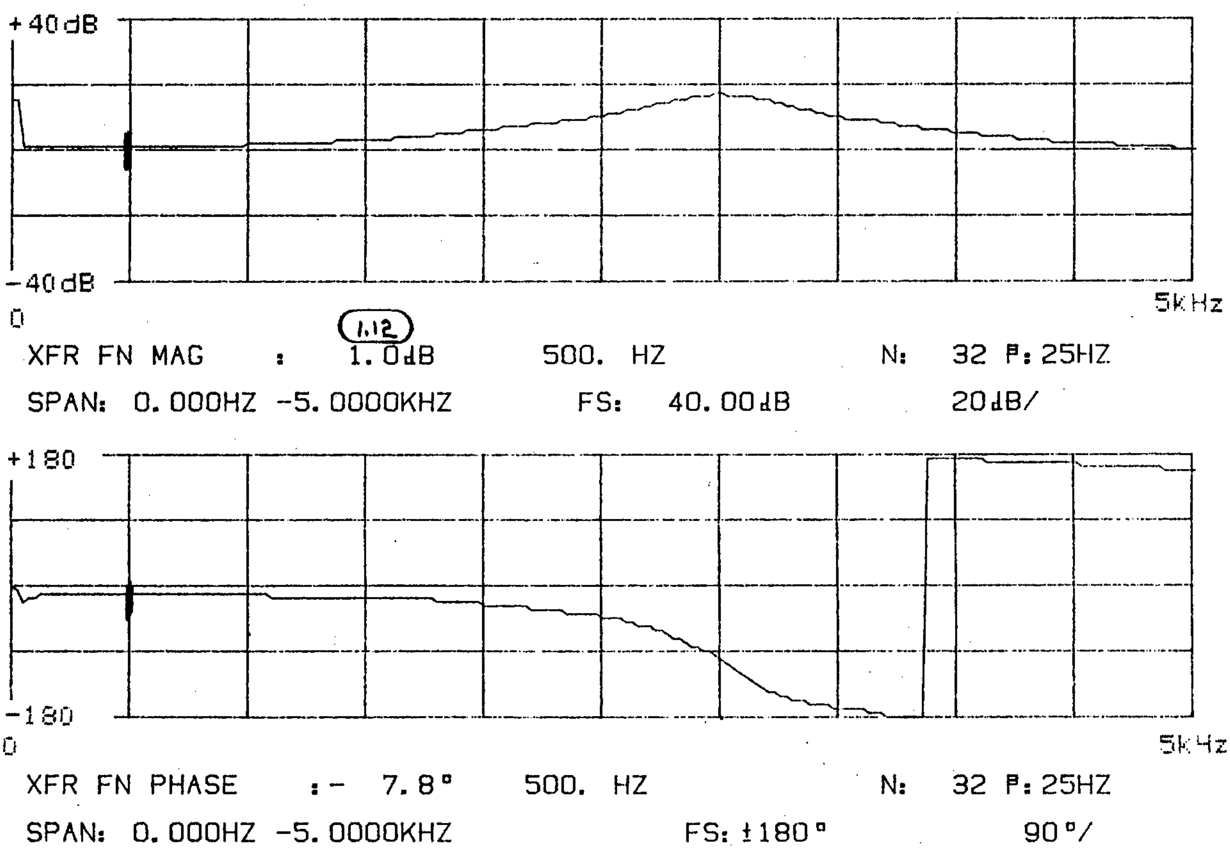


Figure 19. Transfer Function Amplitude and Phase for PCB SN867 vs Columbia 902H

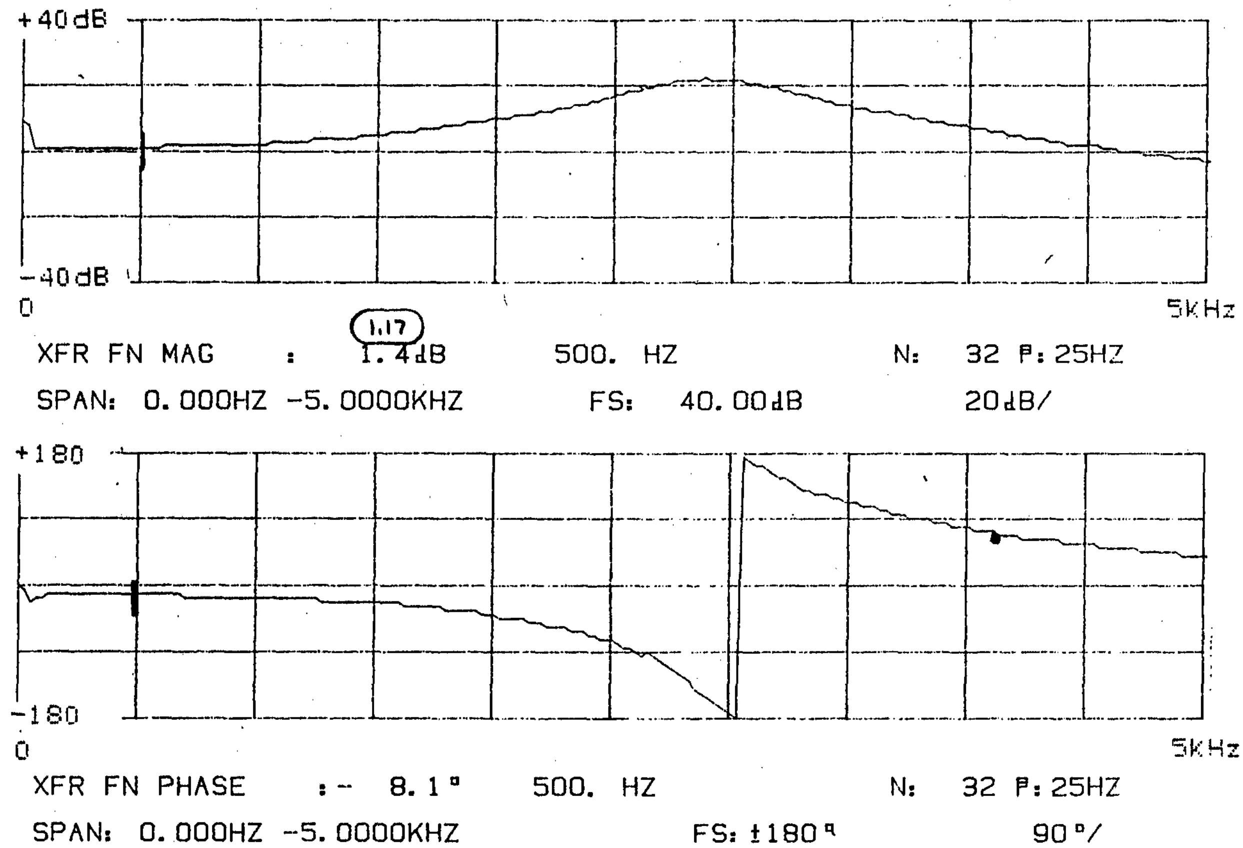


Figure 20. Transfer Function Amplitude and Phase for PCB SN1139 vs Columbia 902H

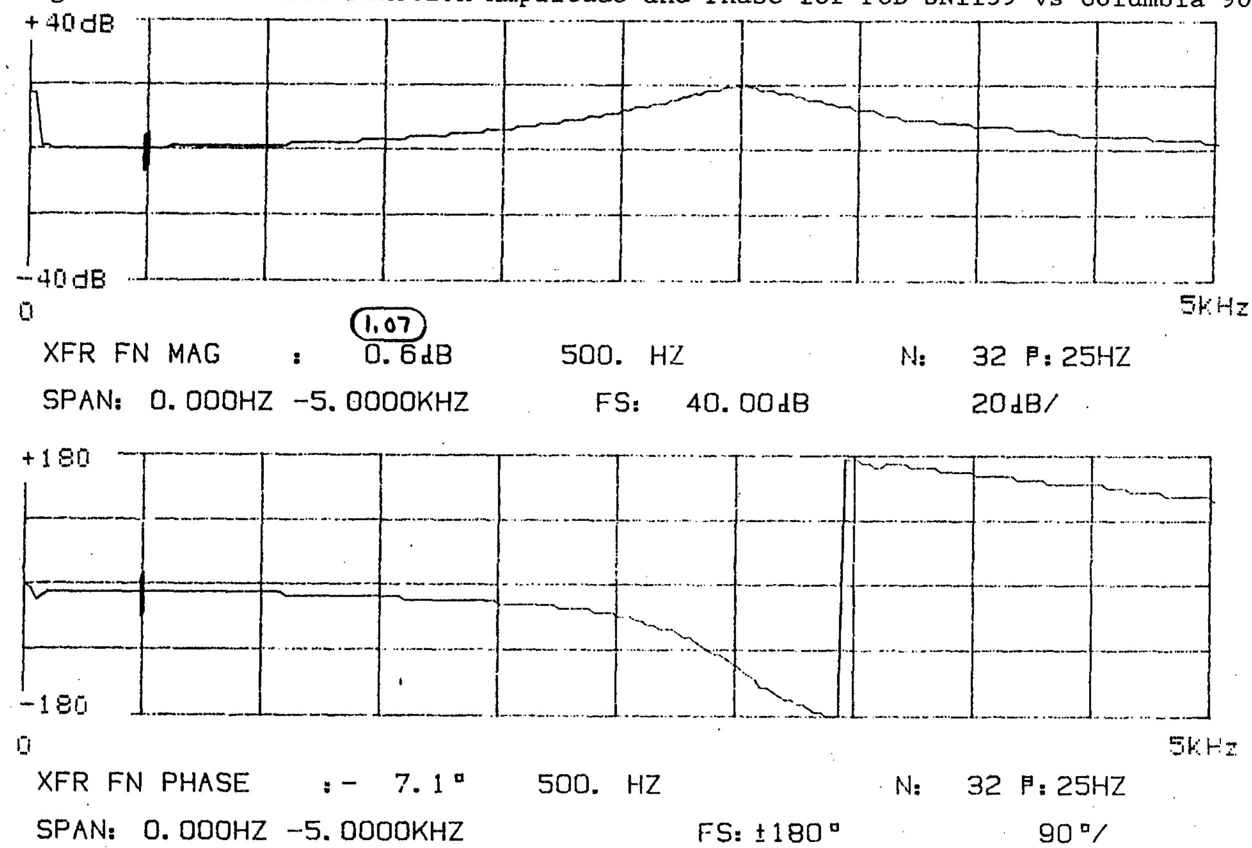


Figure 21. Transfer Function Amplitude and Phase for PCB SN1153 vs Columbia 902H

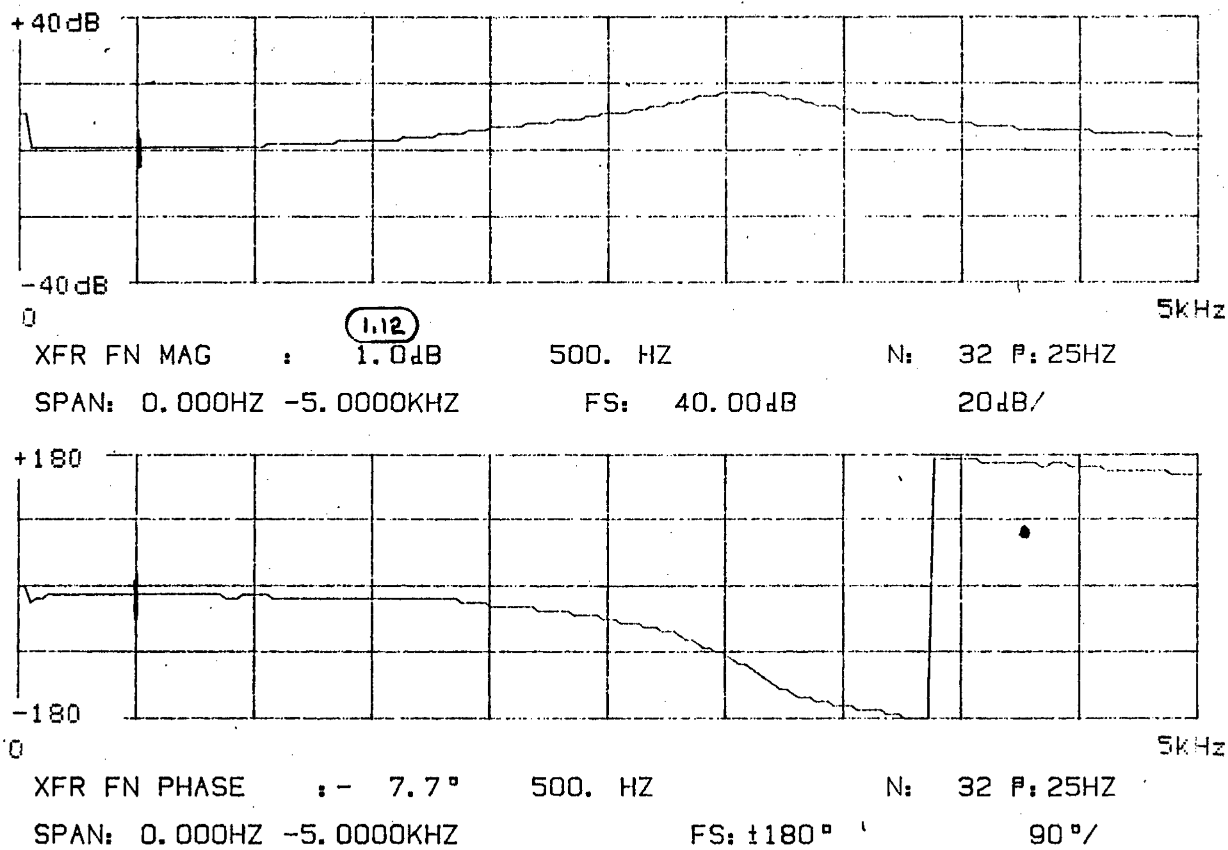


Figure 22. Transfer Function Amplitude and Phase for PCB SN1170 vs Columbia 902H

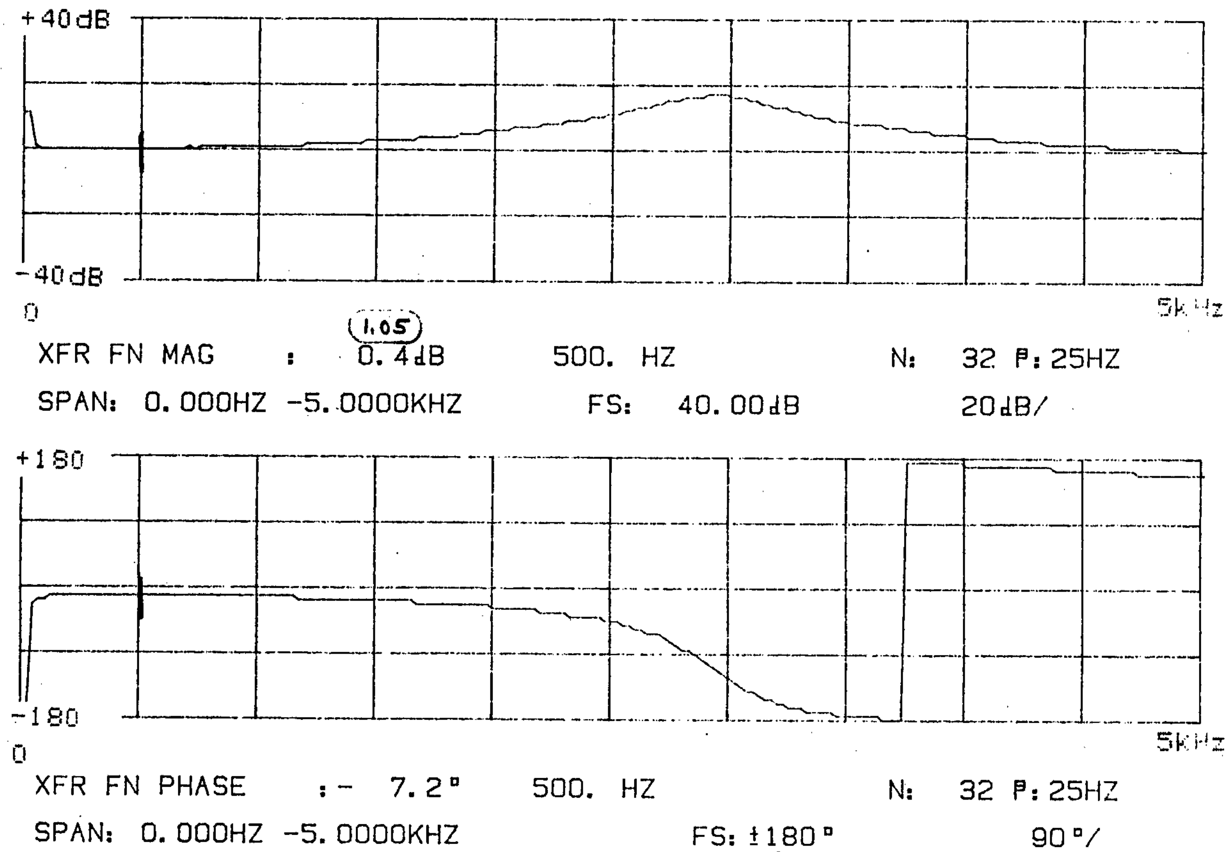


Figure 23. Transfer Function Amplitude and Phase for PCB SN1174 vs Columbia 902H

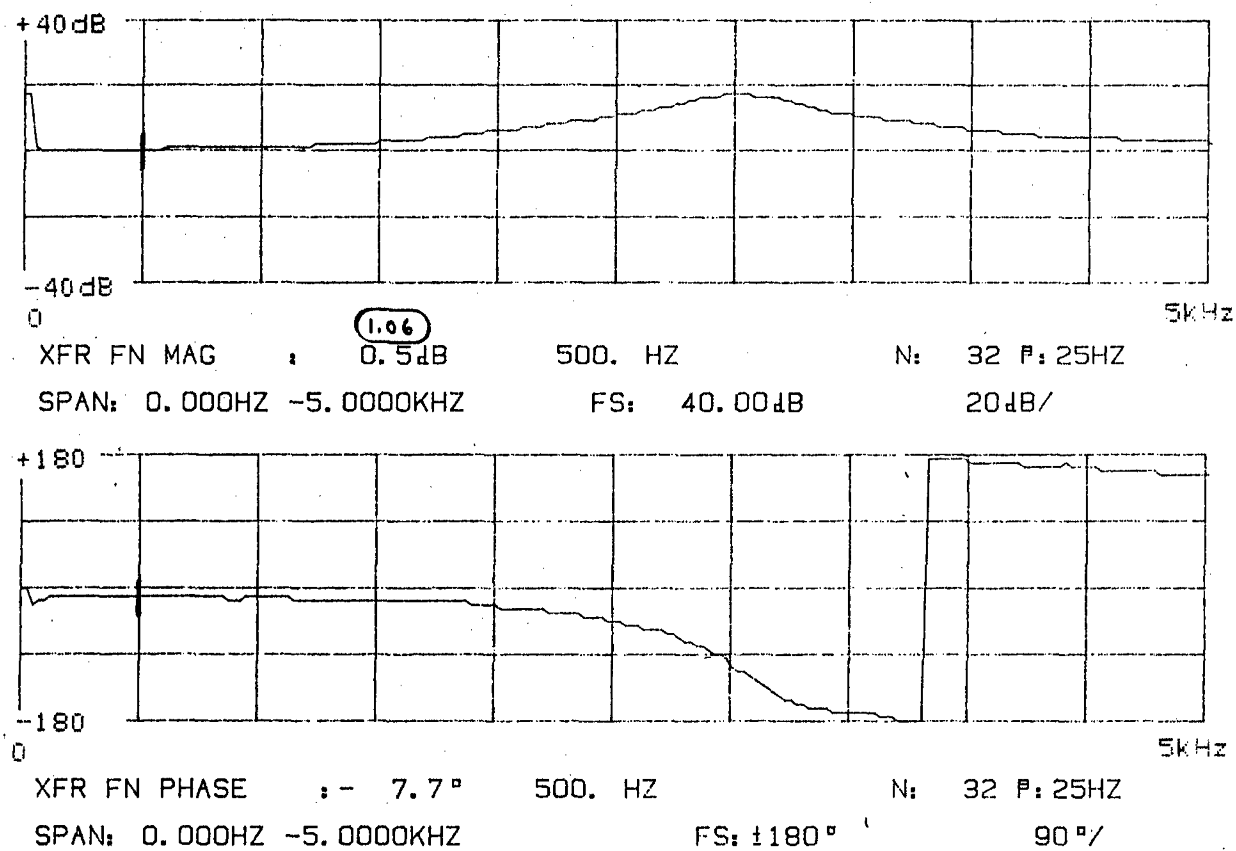


Figure 24. Transfer Function Amplitude and Phase for PCB SN1193 vs Columbia 902H

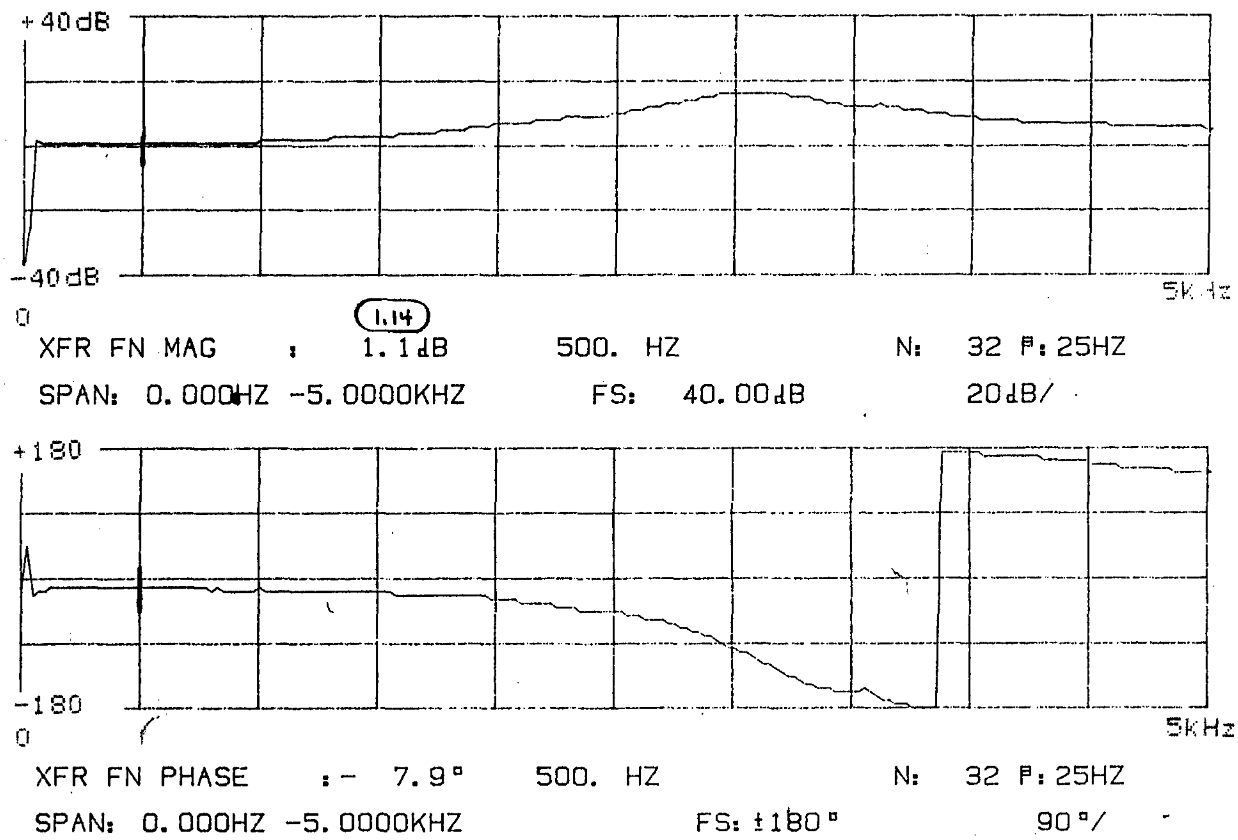


Figure 25. Transfer Function Amplitude and Phase for PCB SN1208 vs Columbia 902H

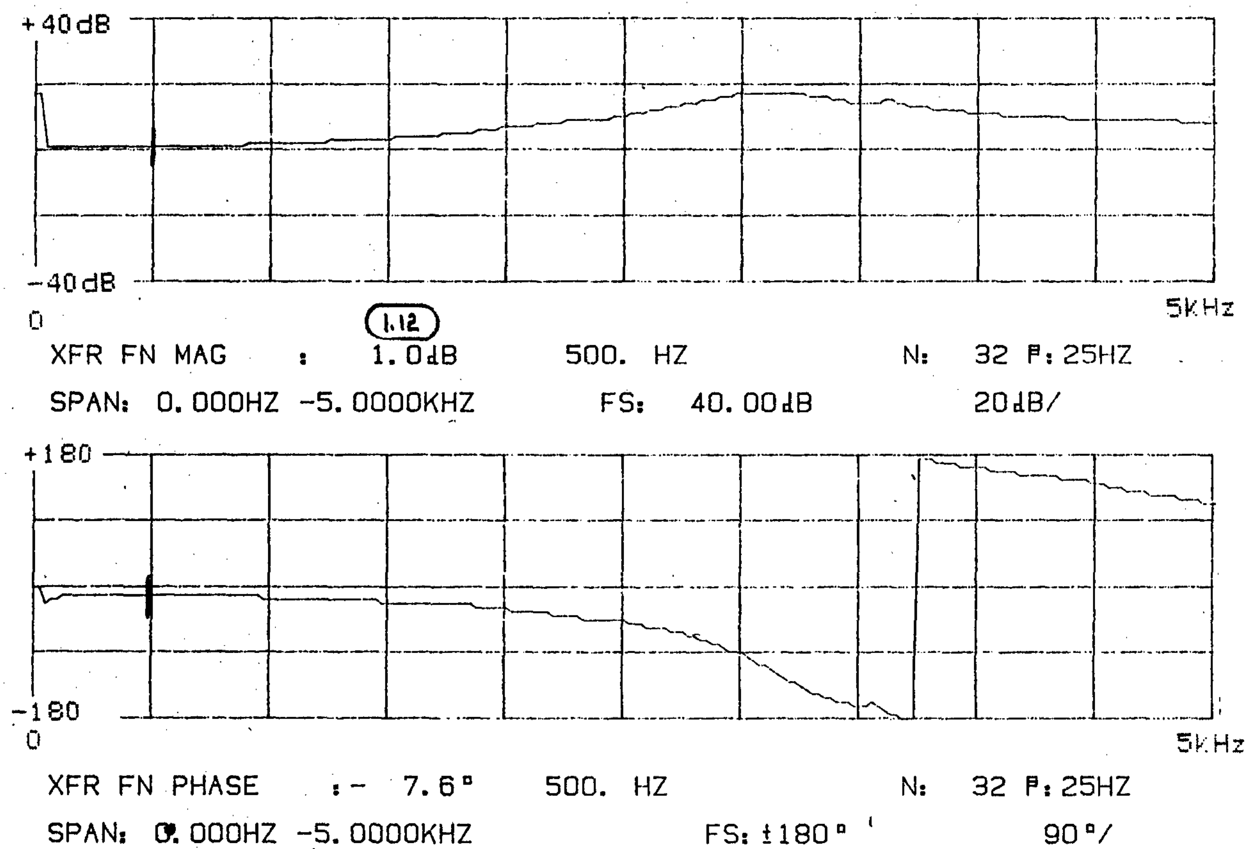


Figure 26. Transfer Function Amplitude and Phase for PCB SN1210 vs Columbia 902H

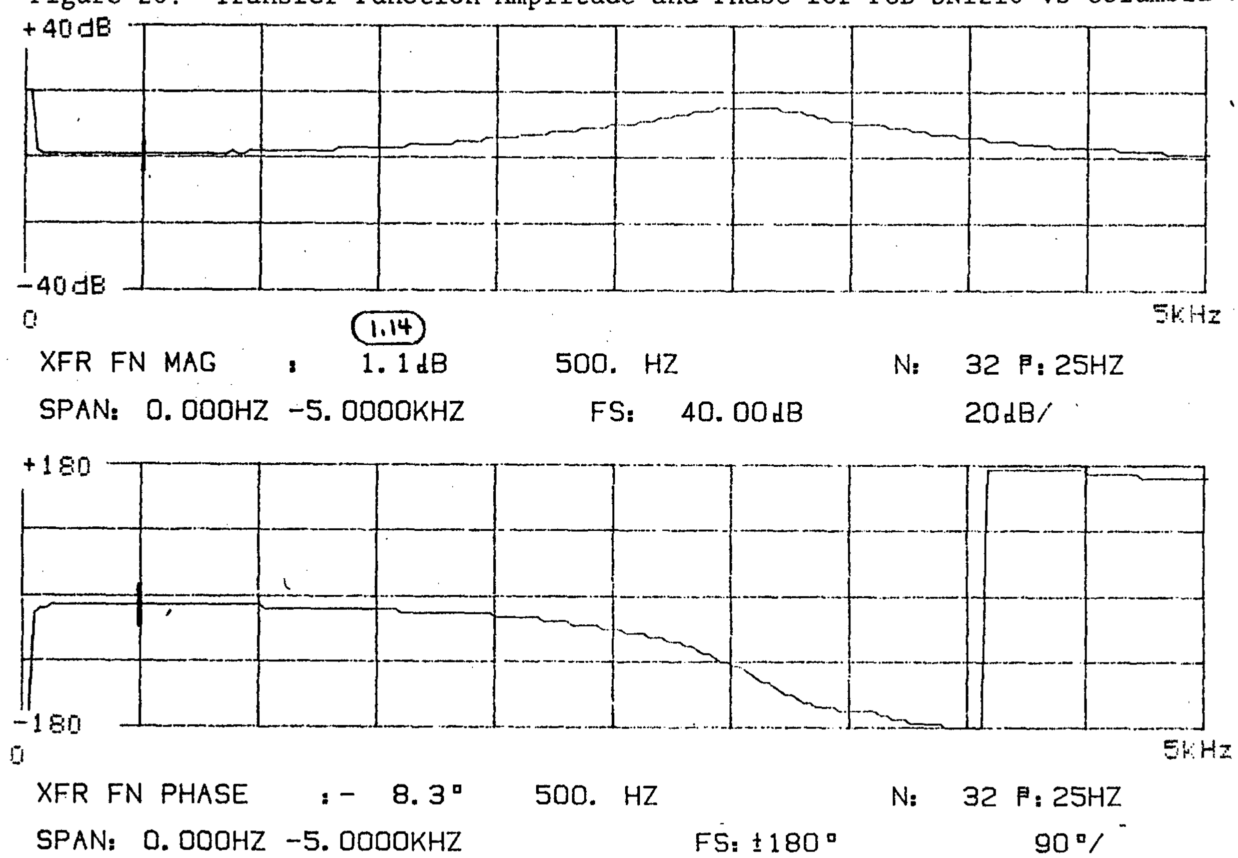


Figure 27. Transfer Function Amplitude and Phase for PCB SN1211 vs Columbia 902H

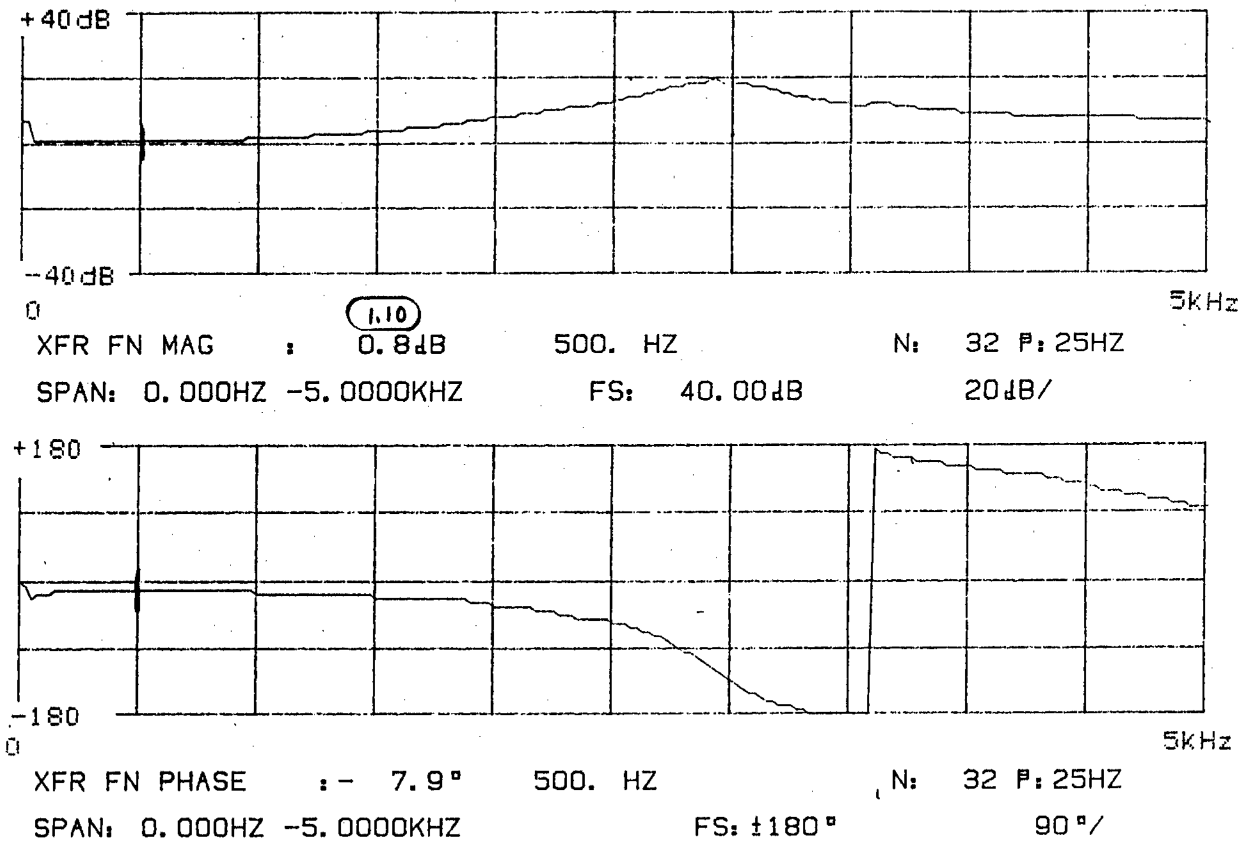


Figure 28. Transfer Function Amplitude and Phase for PCB SN1213 vs Columbia 902H

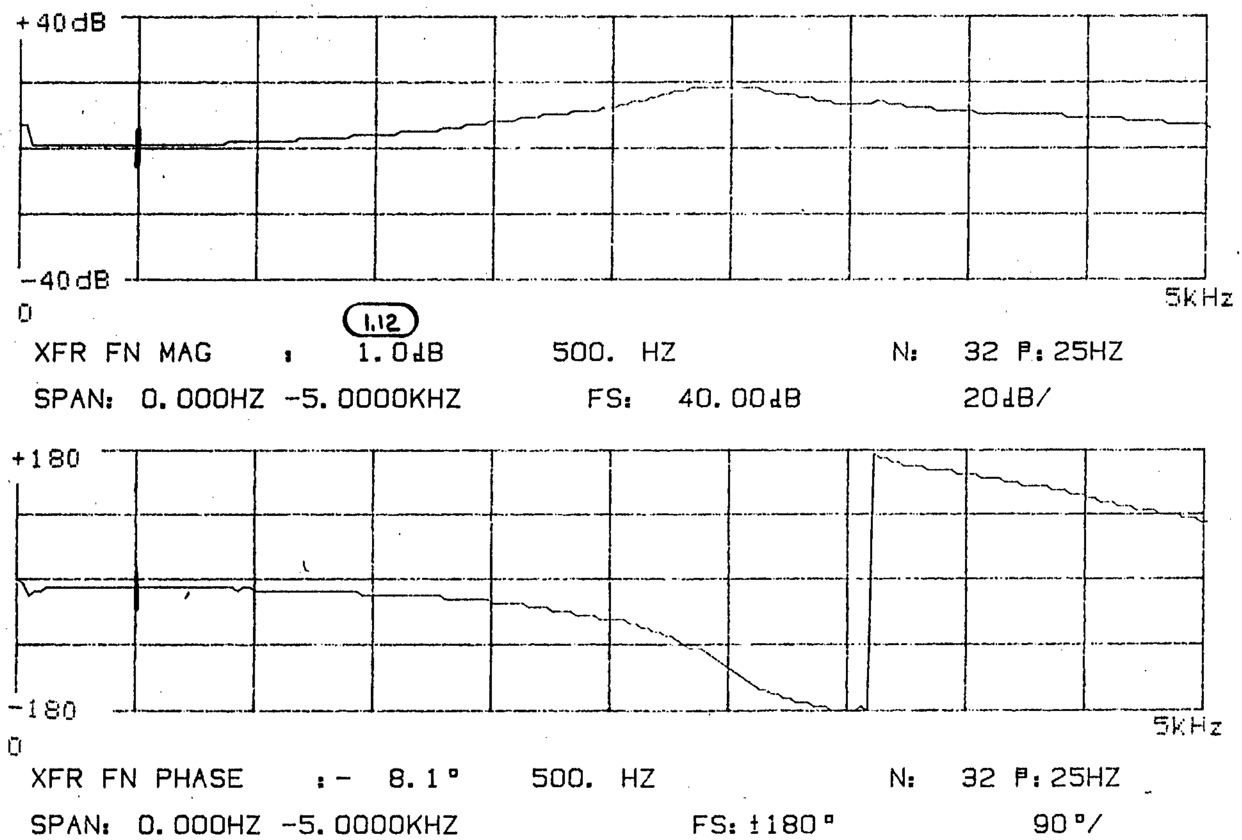


Figure 29. Transfer Function Amplitude and Phase for PCB SN1215 vs Columbia 902H

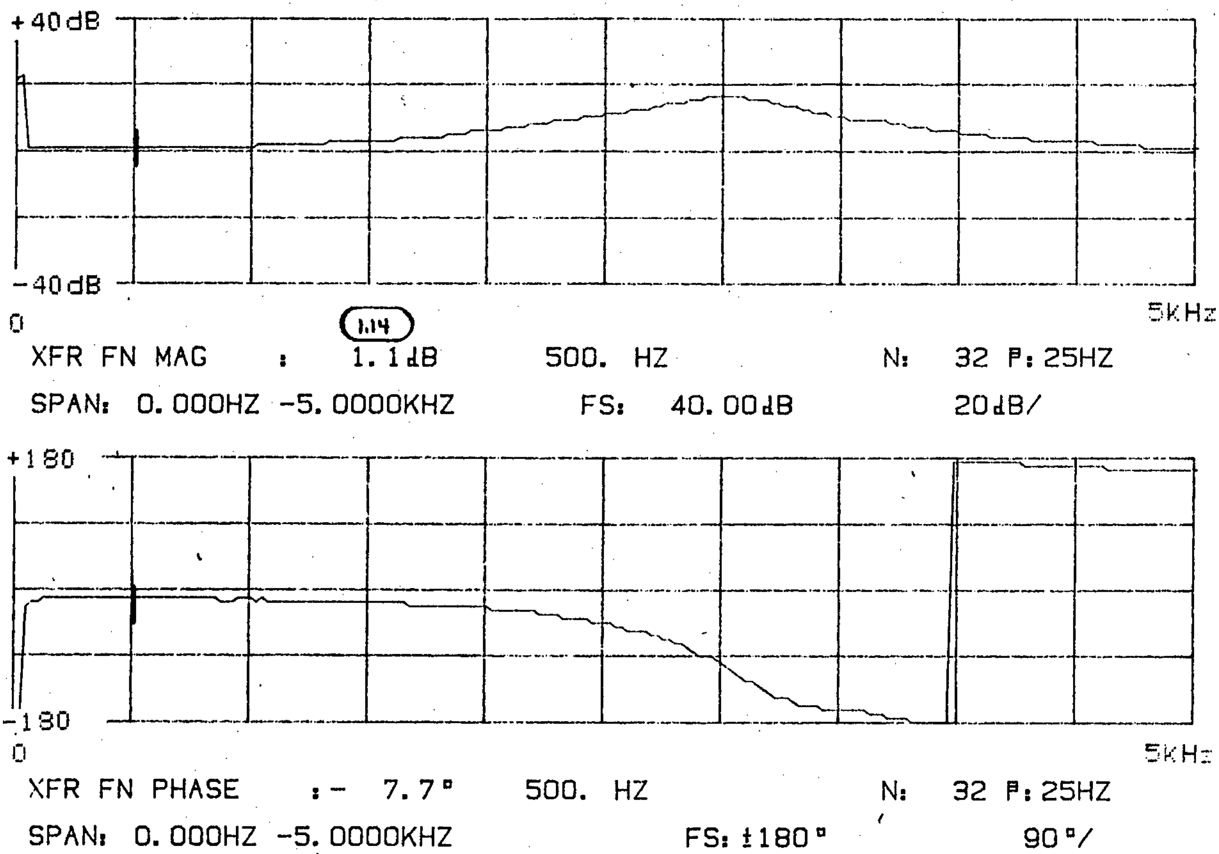


Figure 30. Transfer Function Amplitude and Phase for PCB SN1218 vs Columbia 902H

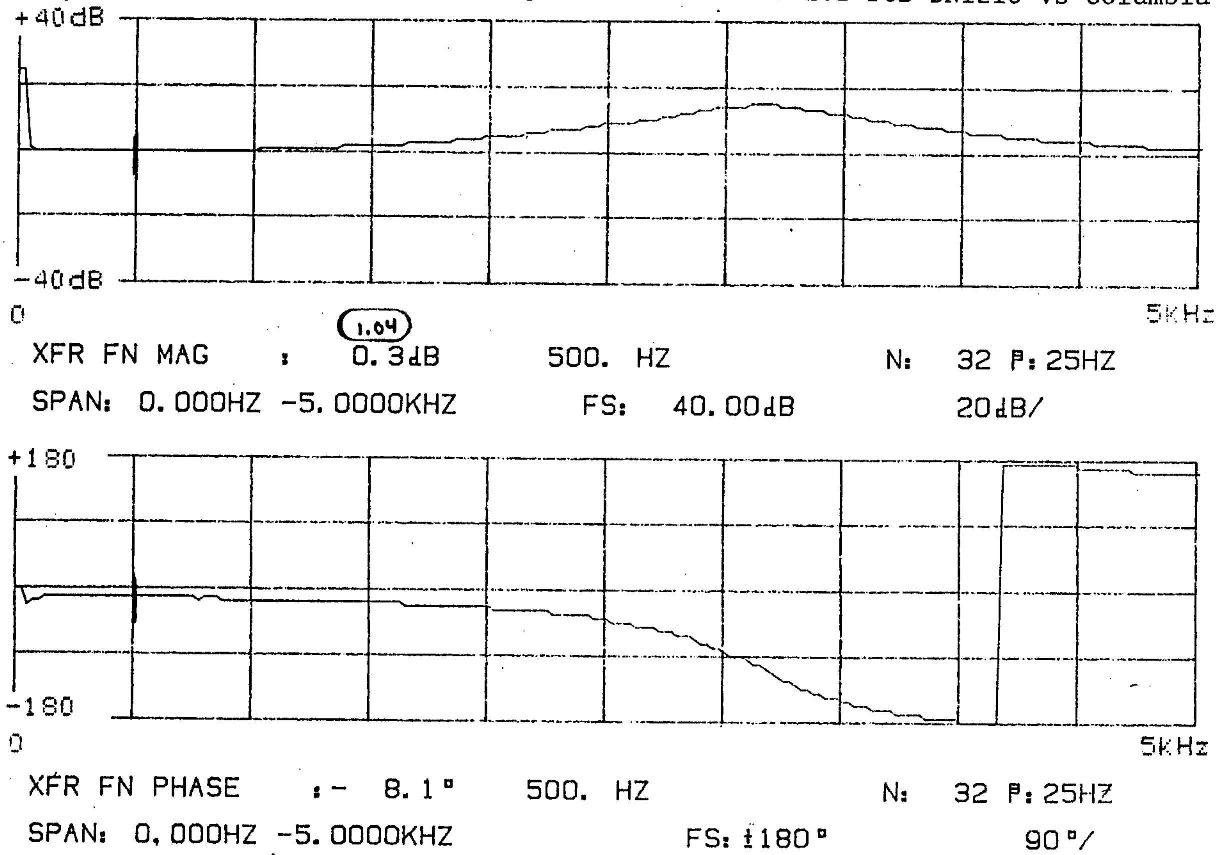


Figure 31. Transfer Function Amplitude and Phase for PCB SN1219 vs Columbia 902H

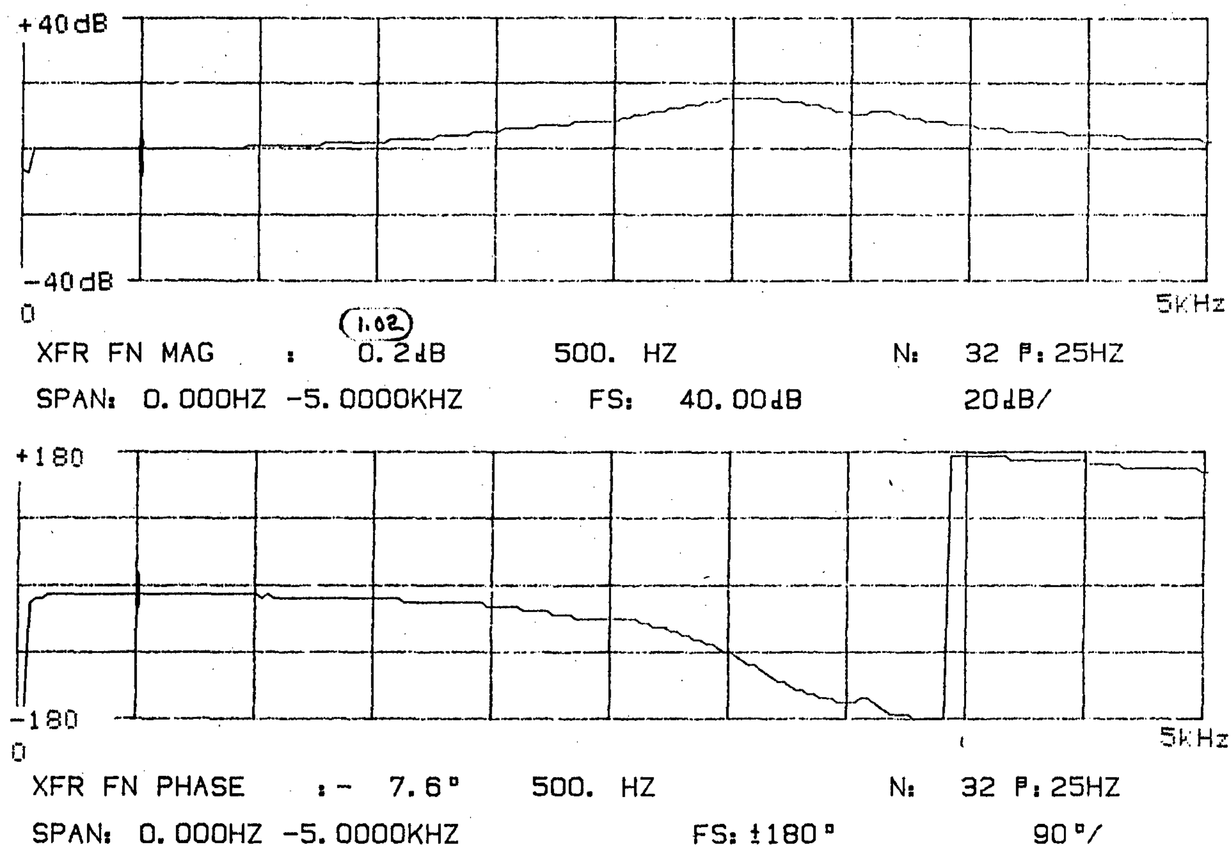


Figure 32. Transfer Function Amplitude and Phase for PCB SN1234 vs Columbia 902H

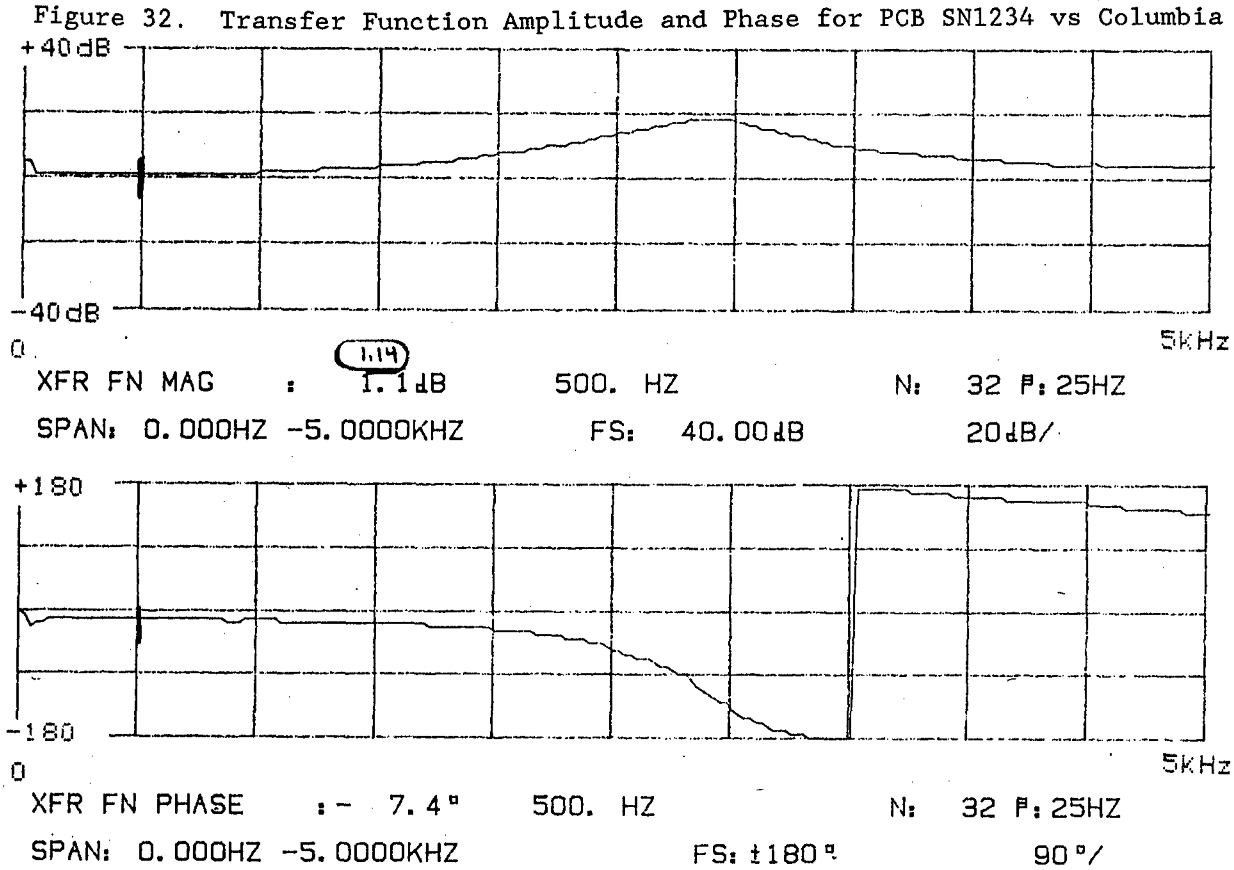


Figure 33. Transfer Function Amplitude and Phase for PCB SN1237 vs Columbia 902H

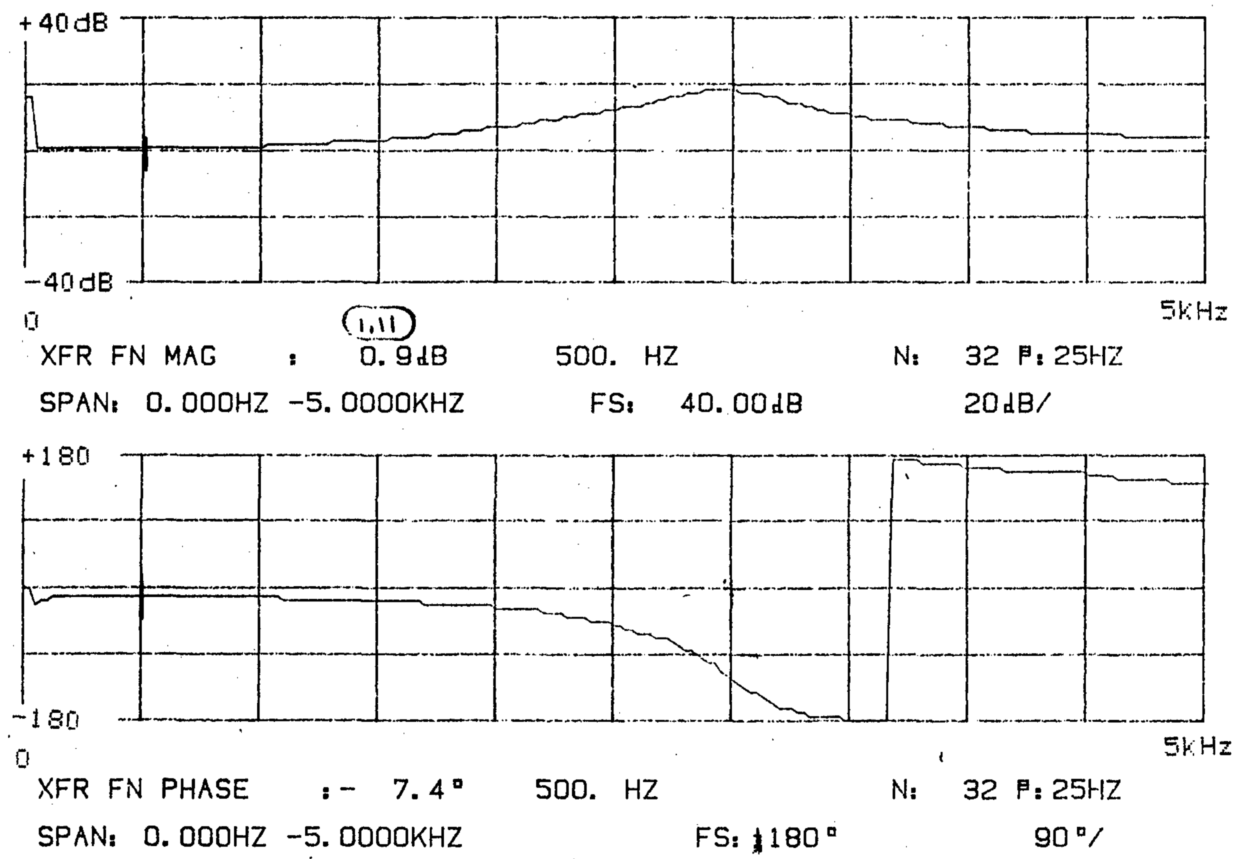


Figure 34. Transfer Function Amplitude and Phase for PCB SN1242 vs Columbia 902H

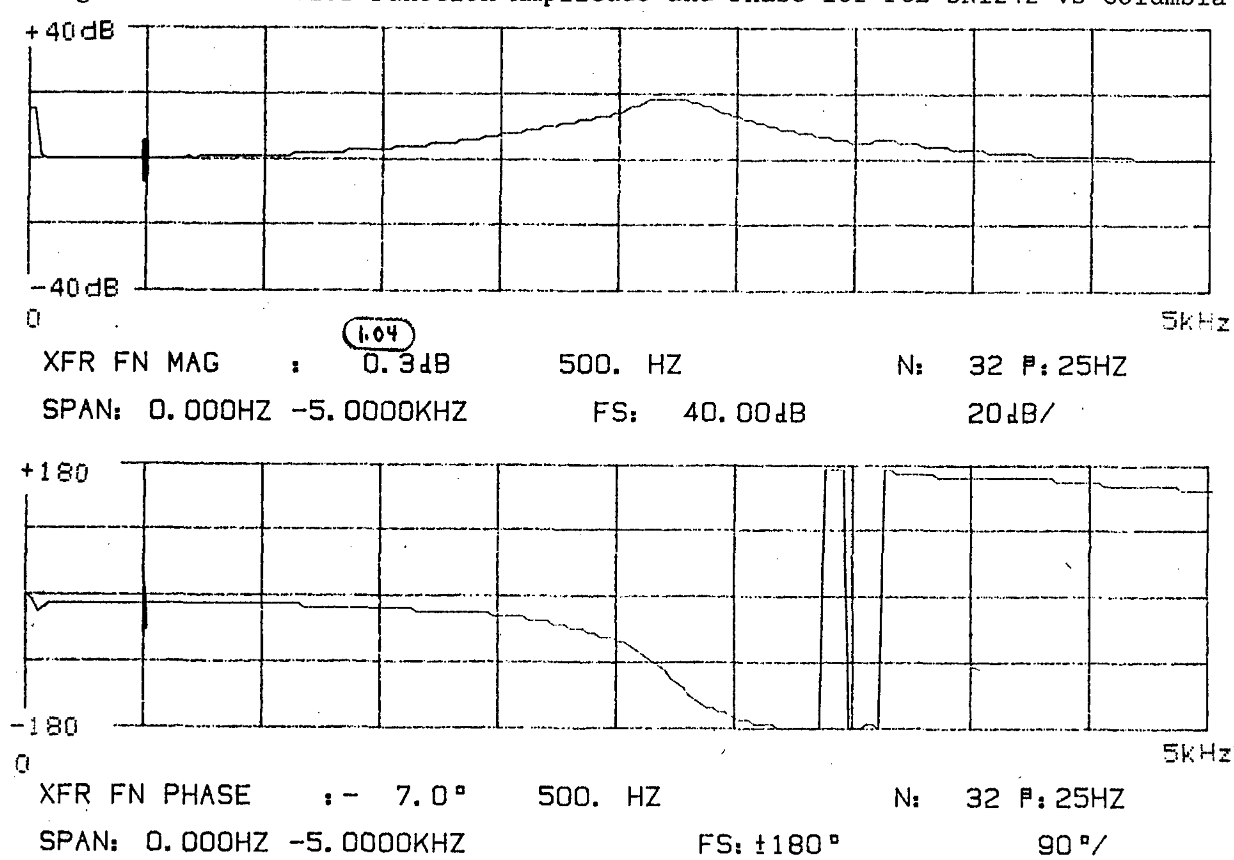


Figure 35. Transfer Function Amplitude and Phase for PCB SN1243 vs Columbia 902H

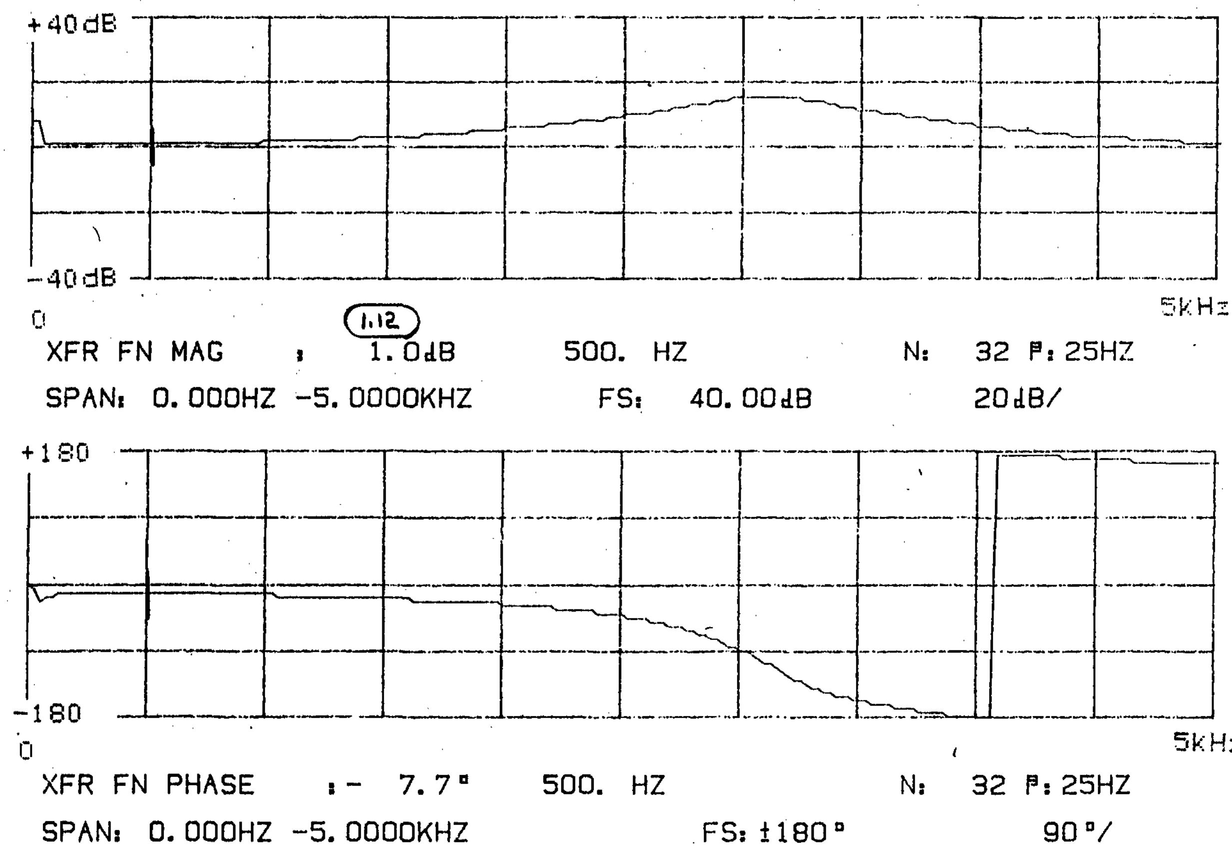


Figure 36. Transfer Function Amplitude and Phase for PCB SN1247 vs Columbia 902H

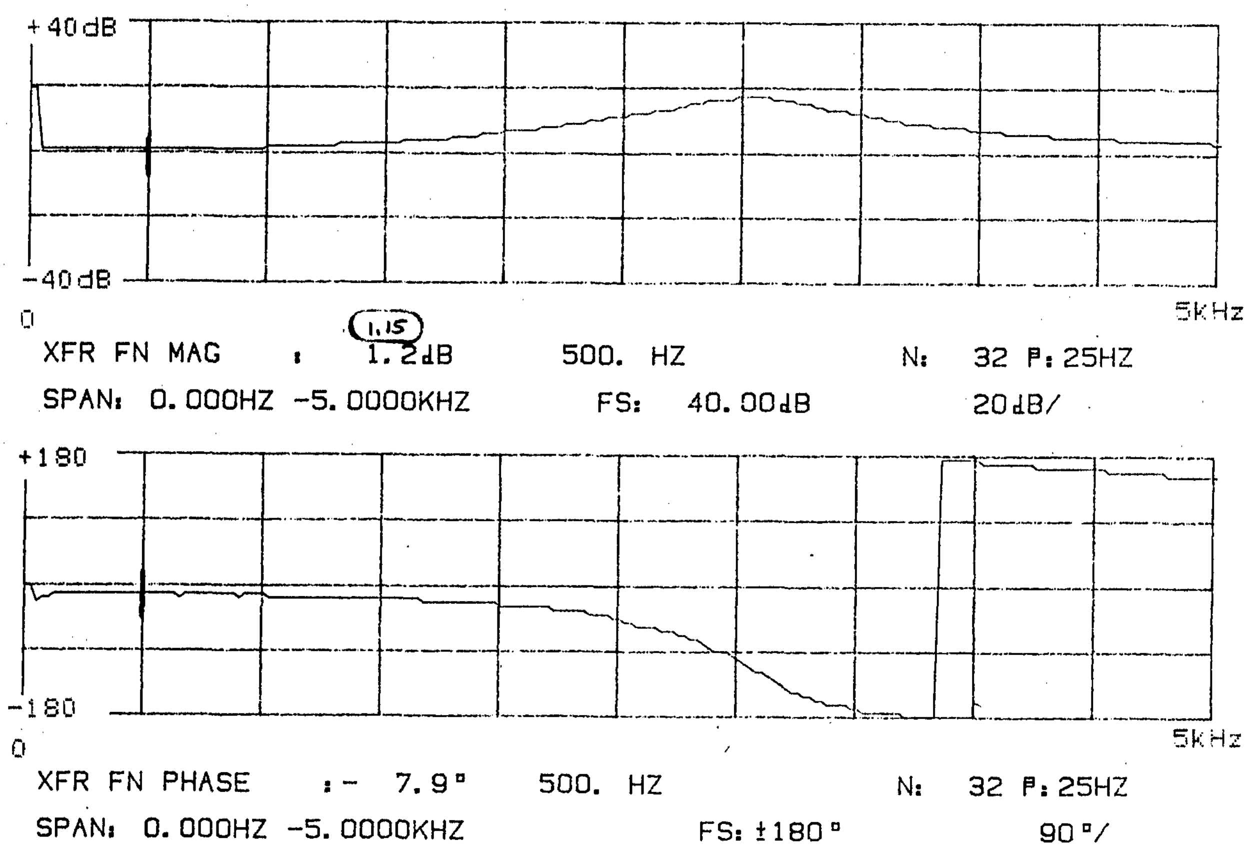


Figure 37. Transfer Function Amplitude and Phase for PCB SN1249 vs Columbia 902H

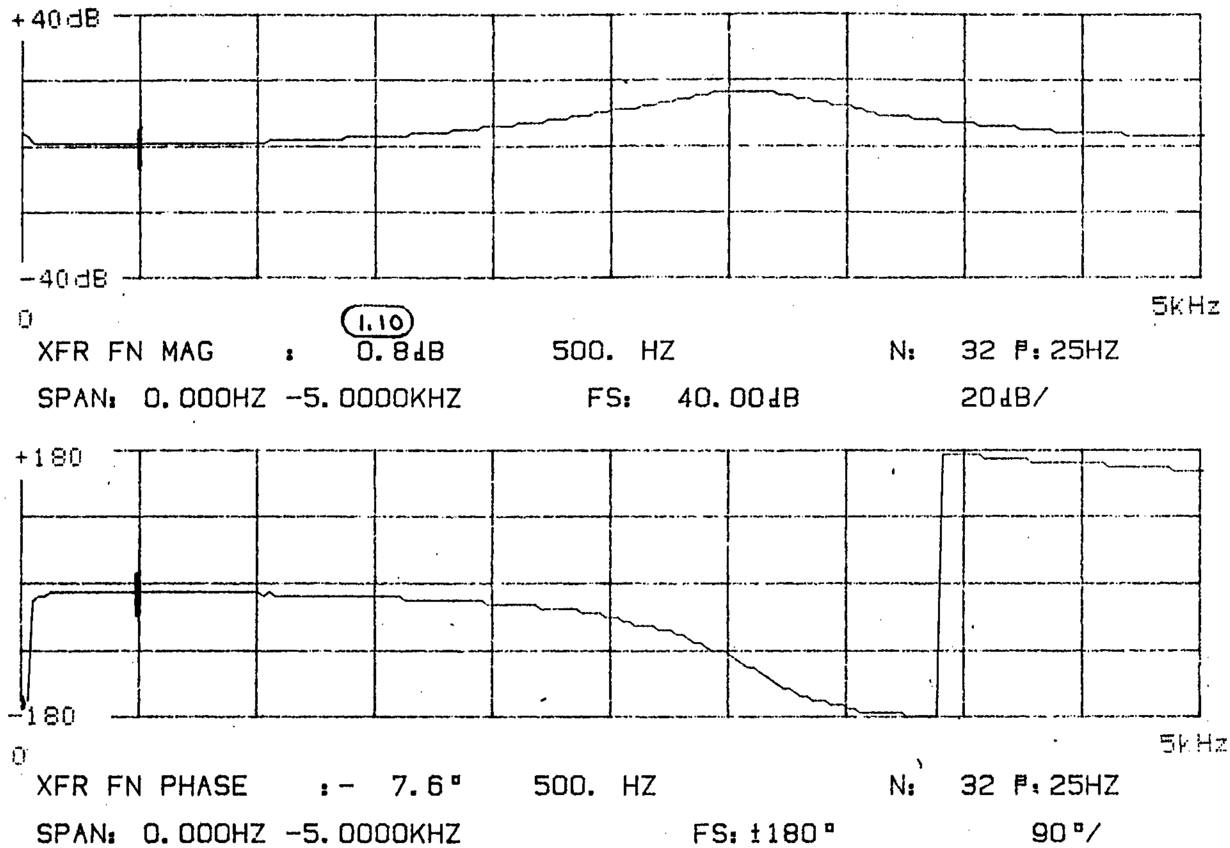


Figure 38. Transfer Function Amplitude and Phase for PCB SN1255 vs Columbia 902H

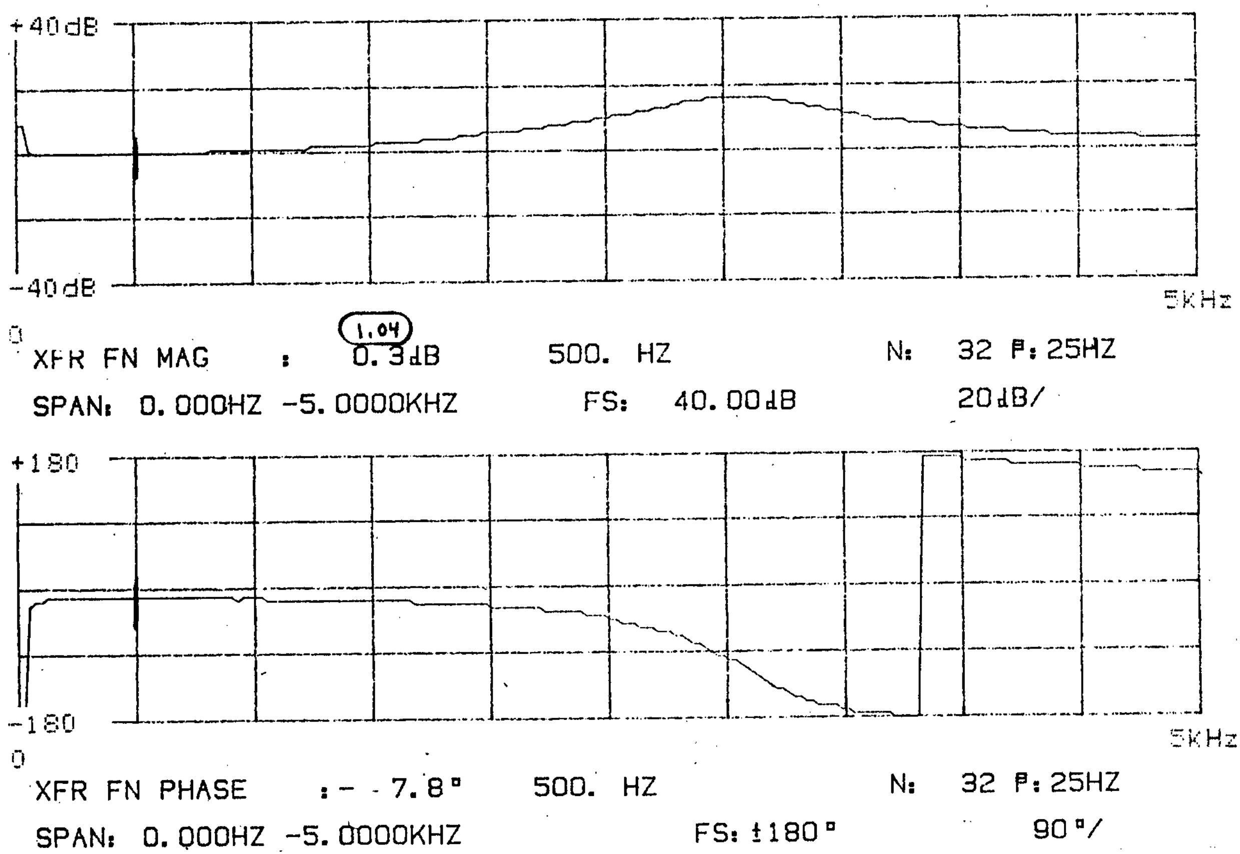
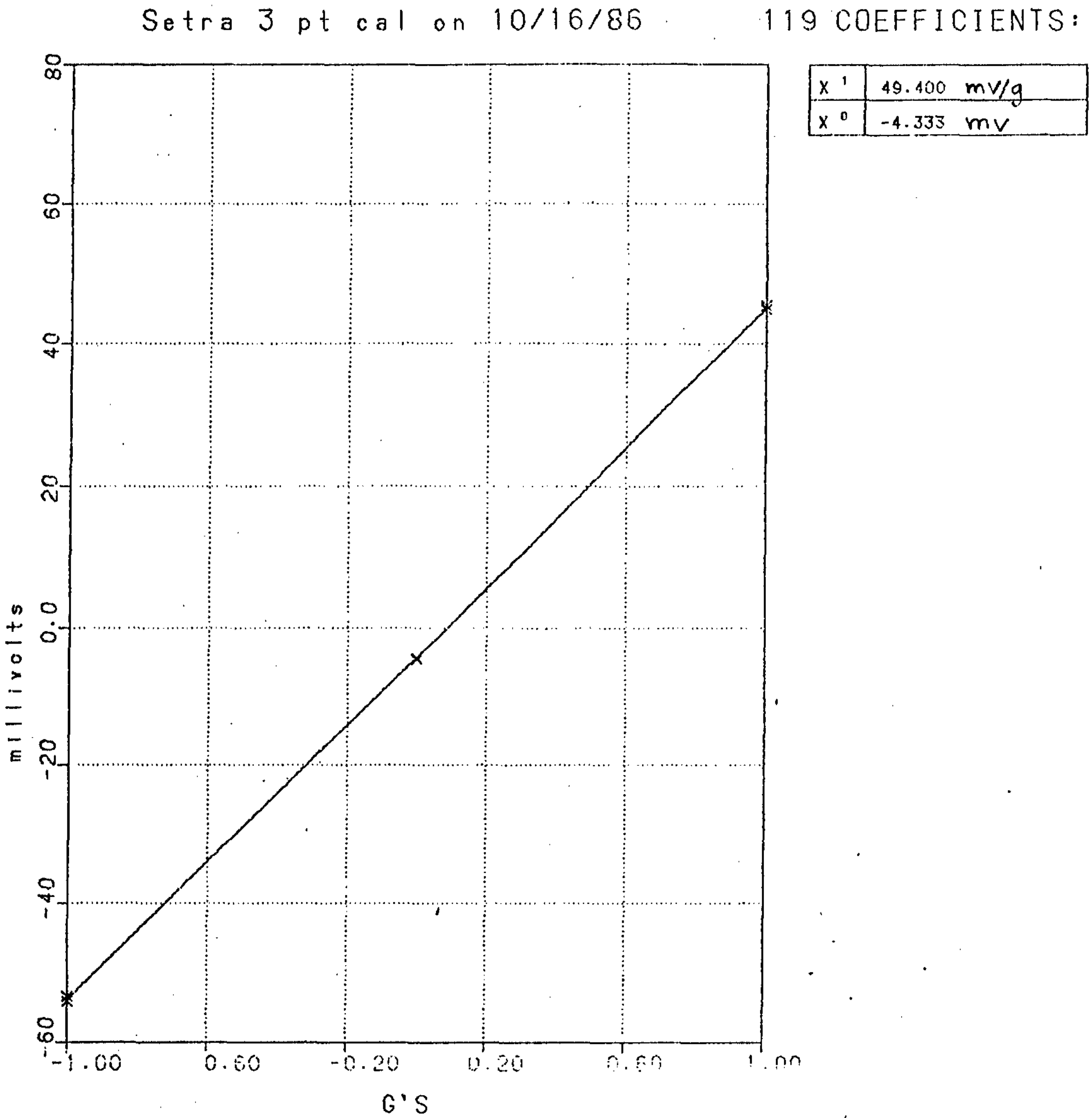


Figure 39. Transfer Function Amplitude and Phase for PCB SN1258 vs Columbia 902H



PLSQ POLYNOMIAL LEAST SQUARE CURVE FIT ERROR ANALYSIS

I	X- GIVEN	Y- GIVEN	Y- FITTED	ERROR	C(I)
1	0.10000E+01	0.44900E+02	0.45067E+02	0.16667E+00	0.49400E+02
2	0.00000E+00	-0.46000E+01	-0.43333E+01	0.26667E+00	-0.43333E+01
3	-0.10000E+01	-0.53300E+02	-0.53733E+02	-0.43334E+00	
4	-0.10000E+01	-0.54000E+02	-0.53733E+02	0.26666E+00	
5	0.00000E+00	-0.44000E+01	-0.43333E+01	0.66667E-01	
6	0.10000E+01	0.45400E+02	0.45067E+02	-0.33333E+00	

EMAX: 0.43334E+00 ERMS: 0.280872E+00 EMEQ: 0.000000E+00

Figure 40. Setra Three Point Calibration Data in Laboratory

SETUP

CH. A SN: 2. 0-01V

CH. B SN: 4. 5+00V

SPAN: 0. 000HZ -200. 00HZ

N: 16. SPECT AVG

MEASUREMENT MODE: CROSS CHANNEL

WEIGHTING FN: HANNING

INTERNAL SAMPLING

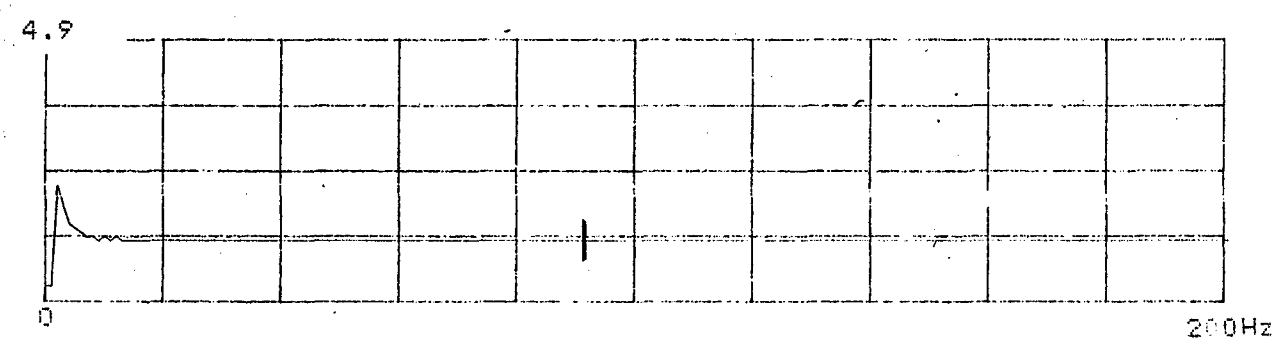
FREE RUN

MODIFIERS: NONE

[V/R] A=4. 9E-02 B=1. 0E+00

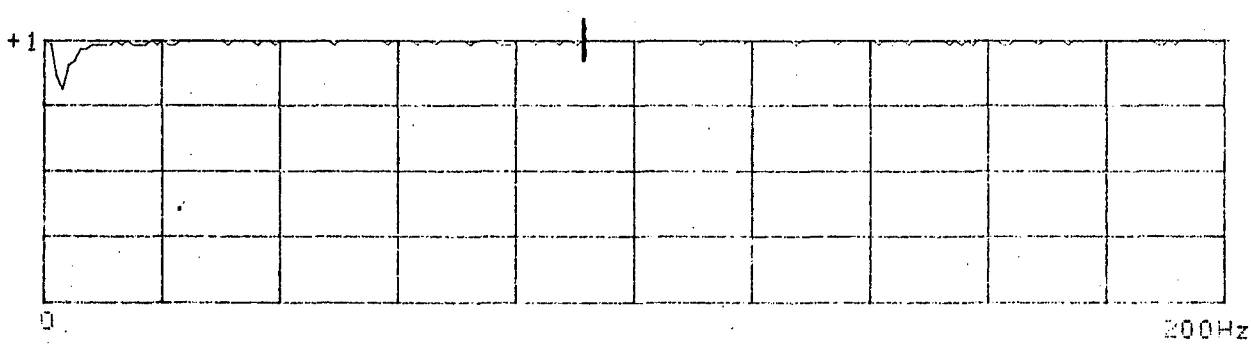
TSG: NOISE

Figure 41. Analyzer Setup for Low Frequency Transfer Function Measurements



XFR FN MAG : 1. 17E+00 91. HZ N: 16 P: 1HZ

SPAN: 0. 000HZ -200. 00HZ FS: 4. 9+00 1. 2+00/



COHER : 1. 00 91. HZ N: 16 P: 1HZ

SPAN: 0. 000HZ -200. 00HZ FS: 1. 0 0. 25/

Figure 42. Transfer Function Amplitude and Coherence for PCB SN857 vs Setra

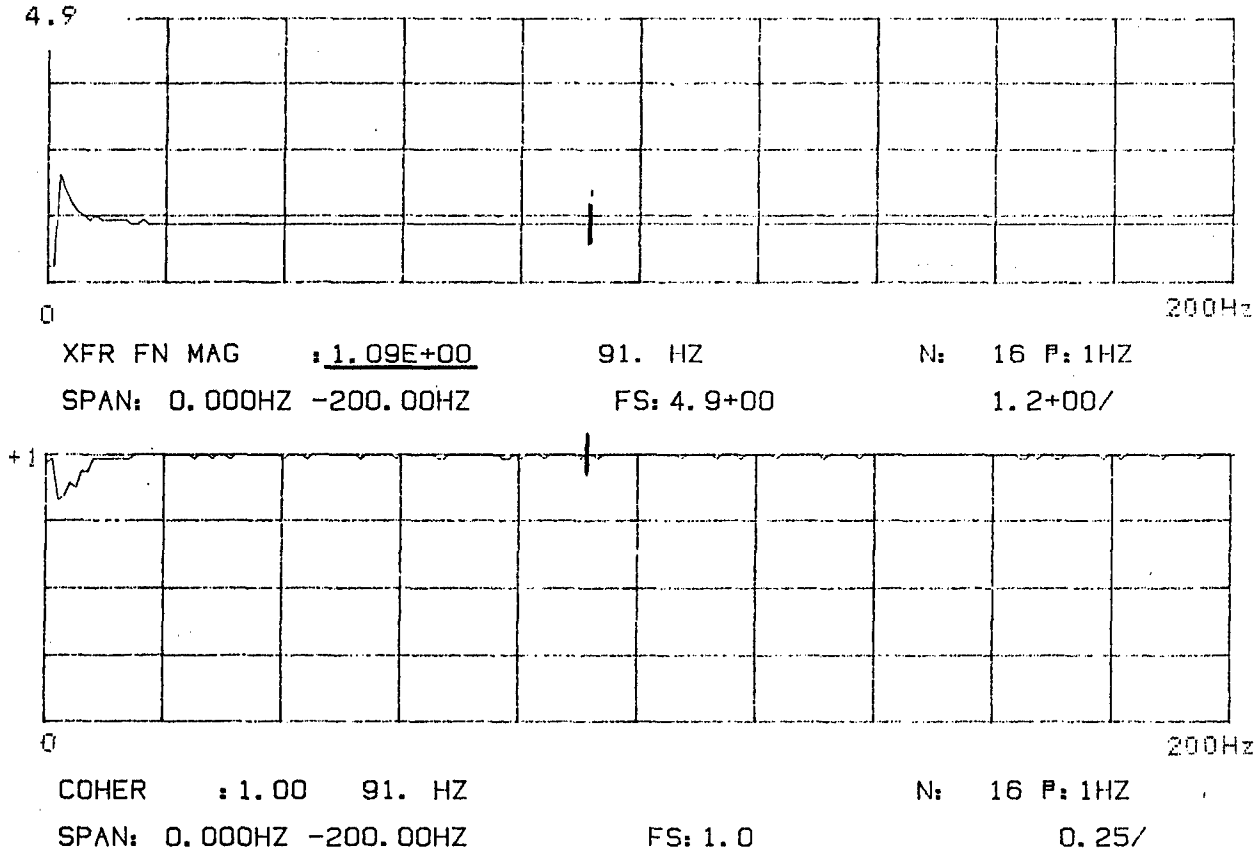


Figure 43. Transfer Function Amplitude and Coherence for PCB SN1091 vs Setra

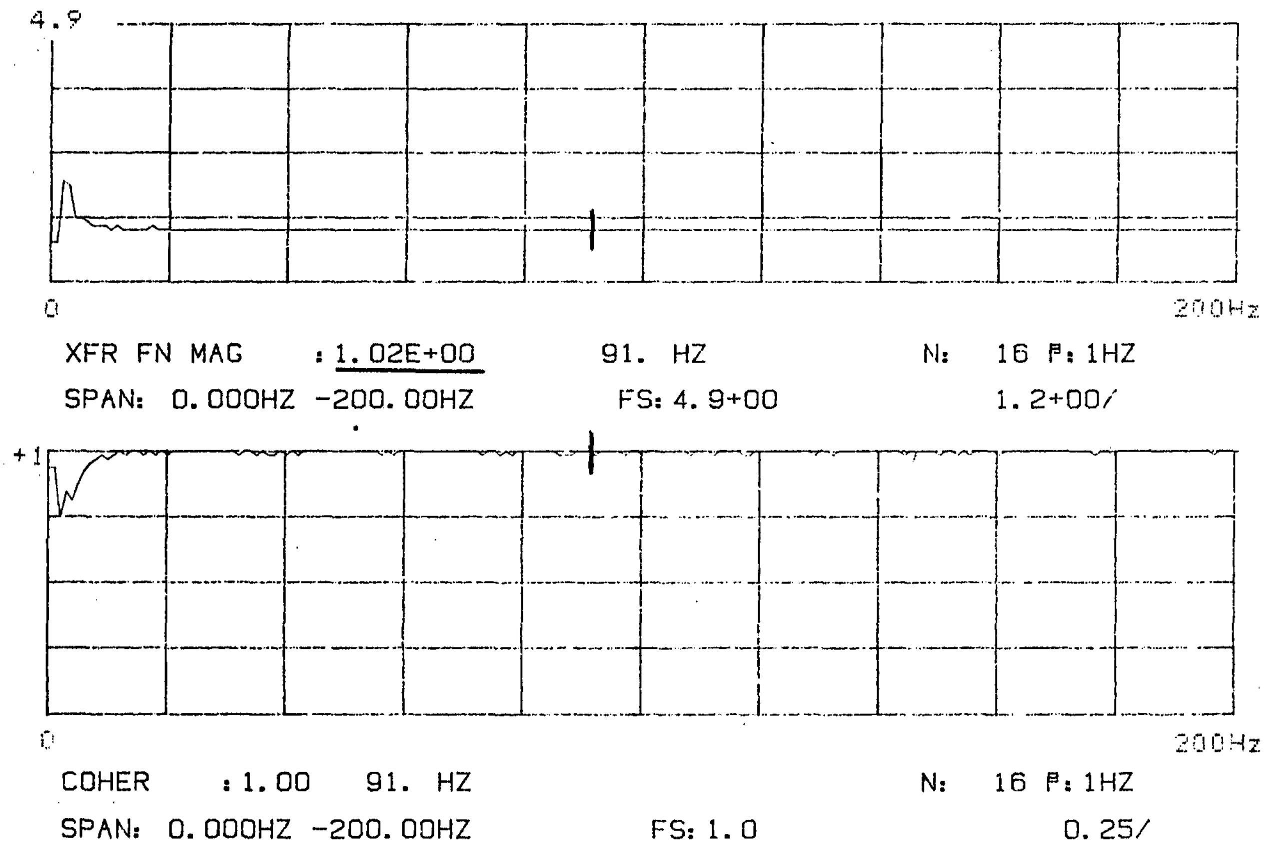
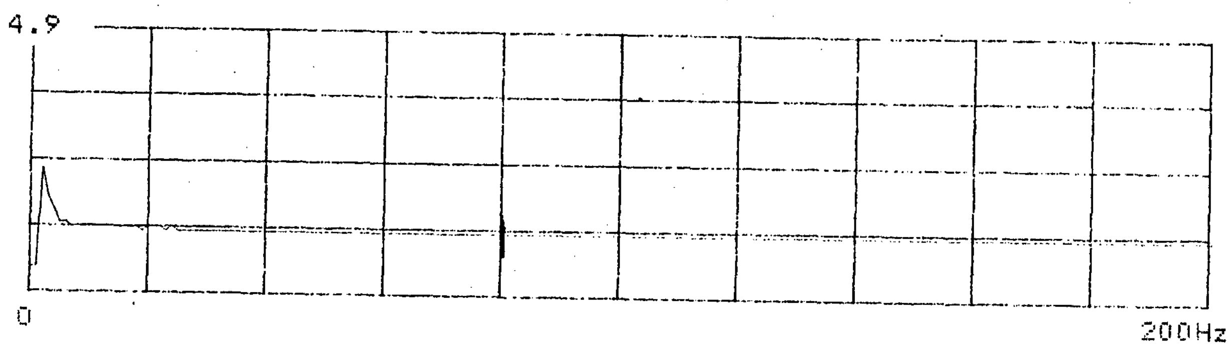
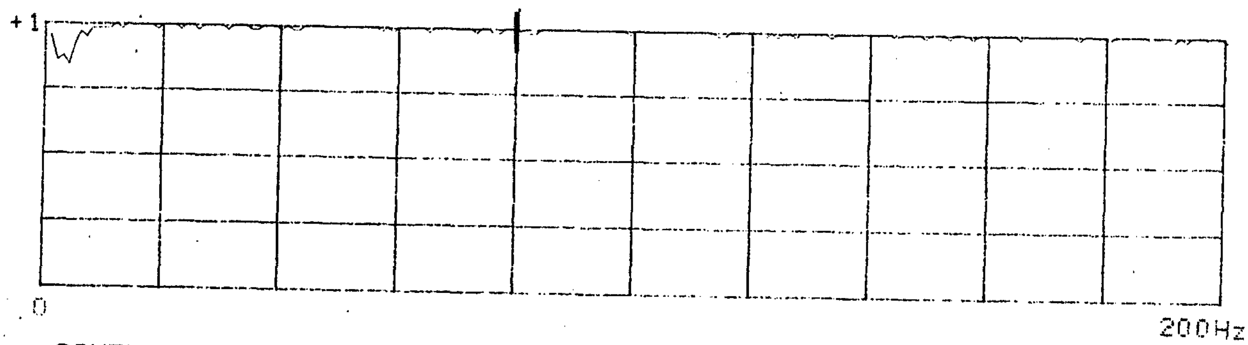


Figure 44. Transfer Function Amplitude and Coherence for PCB SN1076 vs Setra



XFR FN MAG : 1.19E+00 80. HZ N: 16 P: 1HZ

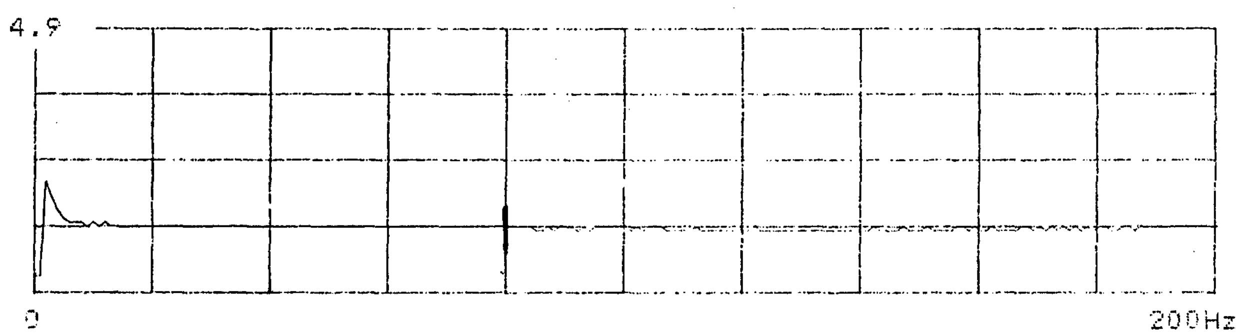
SPAN: 0.000HZ -200.00HZ FS: 4.9+00 1.2+00/



COHER : 1.00 80. HZ N: 16 P: 1HZ

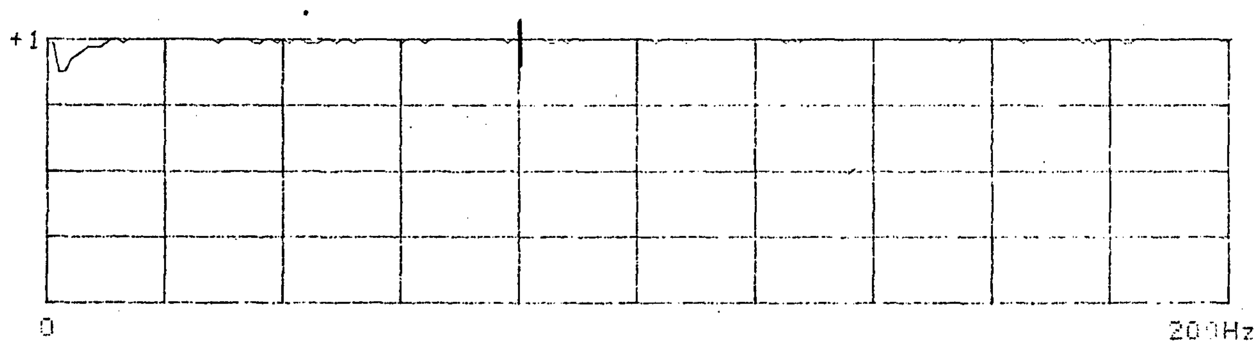
SPAN: 0.000HZ -200.00HZ FS: 1.0 0.25/

Figure 45. Transfer Function Amplitude and Coherence for PCB SN1063 vs Setra



XFR FN MAG : 1.22E+00 80. HZ N: 16 P: 1HZ

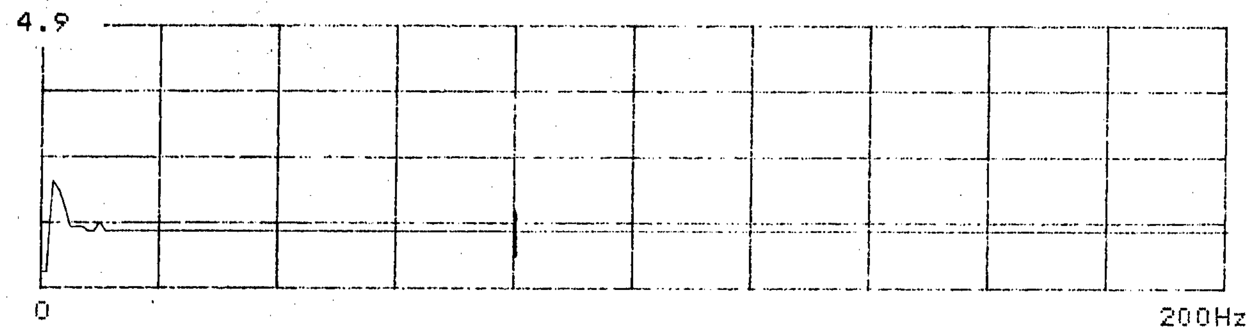
SPAN: 0.000HZ -200.00HZ FS: 4.9+00 1.2+00/



COHER : 1.00 80. HZ N: 16 P: 1HZ

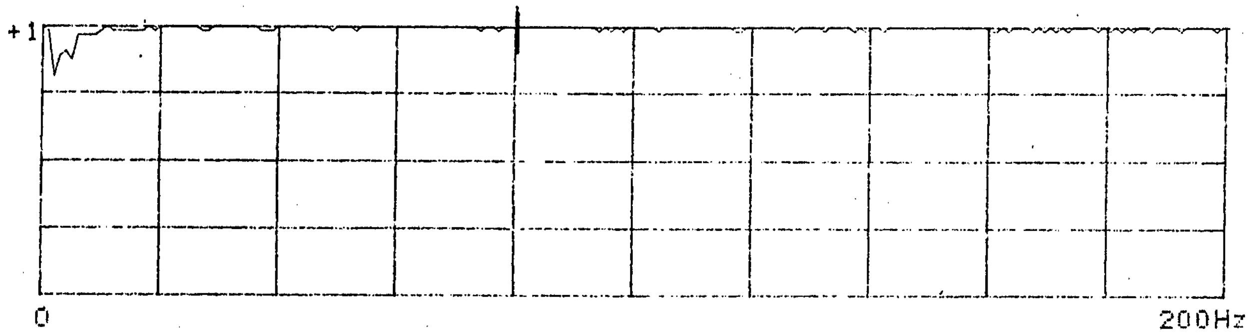
SPAN: 0.000HZ -200.00HZ FS: 1.0 0.25/

Figure 46. Transfer Function Amplitude and Coherence for PCB SN936 vs Setra



XFR FN MAG : 1.07E+00 80. HZ N: 16 P: 1HZ

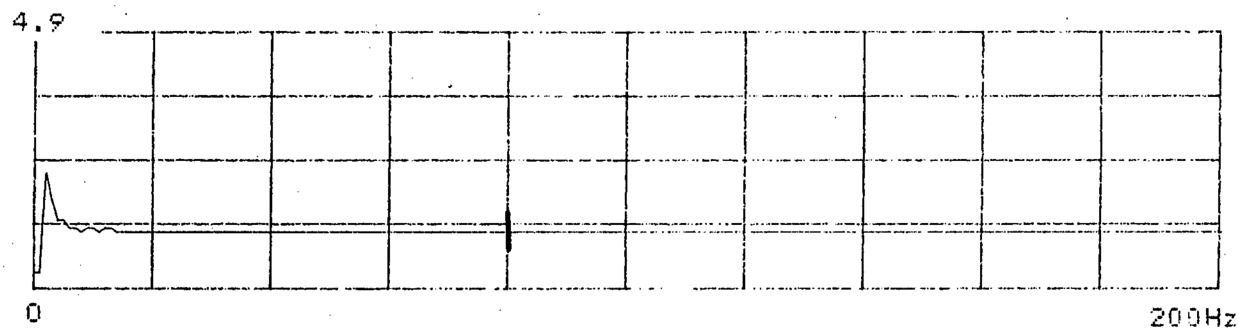
SPAN: 0.000HZ -200.00HZ FS: 4.9+00 1.2+00/



COHER : 1.00 80. HZ N: 16 P: 1HZ

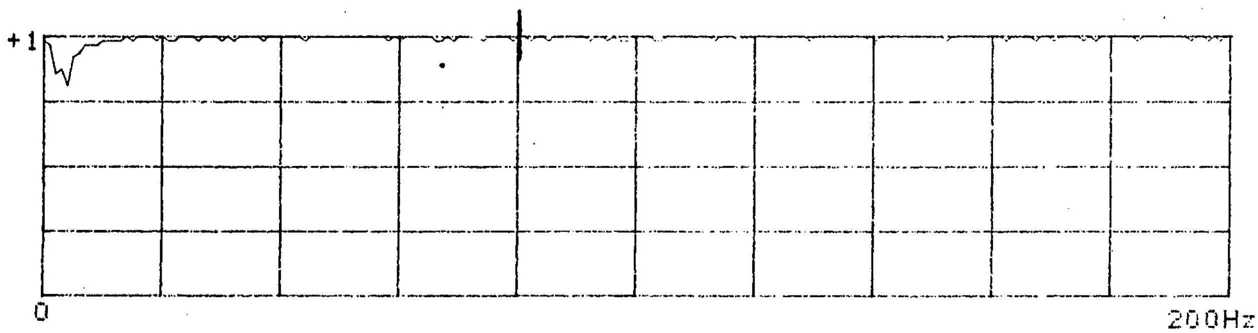
SPAN: 0.000HZ -200.00HZ FS: 1.0 0.25/

Figure 47. Transfer Function Amplitude and Coherence for PCB SN1089 vs Setra



XFR FN MAG : 1.08E+00 80. HZ N: 16 P: 1HZ

SPAN: 0.000HZ -200.00HZ FS: 4.9+00 1.2+00/



COHER : 1.00 80. HZ N: 16 P: 1HZ

SPAN: 0.000HZ -200.00HZ FS: 1.0 0.25/

Figure 48. Transfer Function Amplitude and Coherence for PCB SN1016 vs Setra

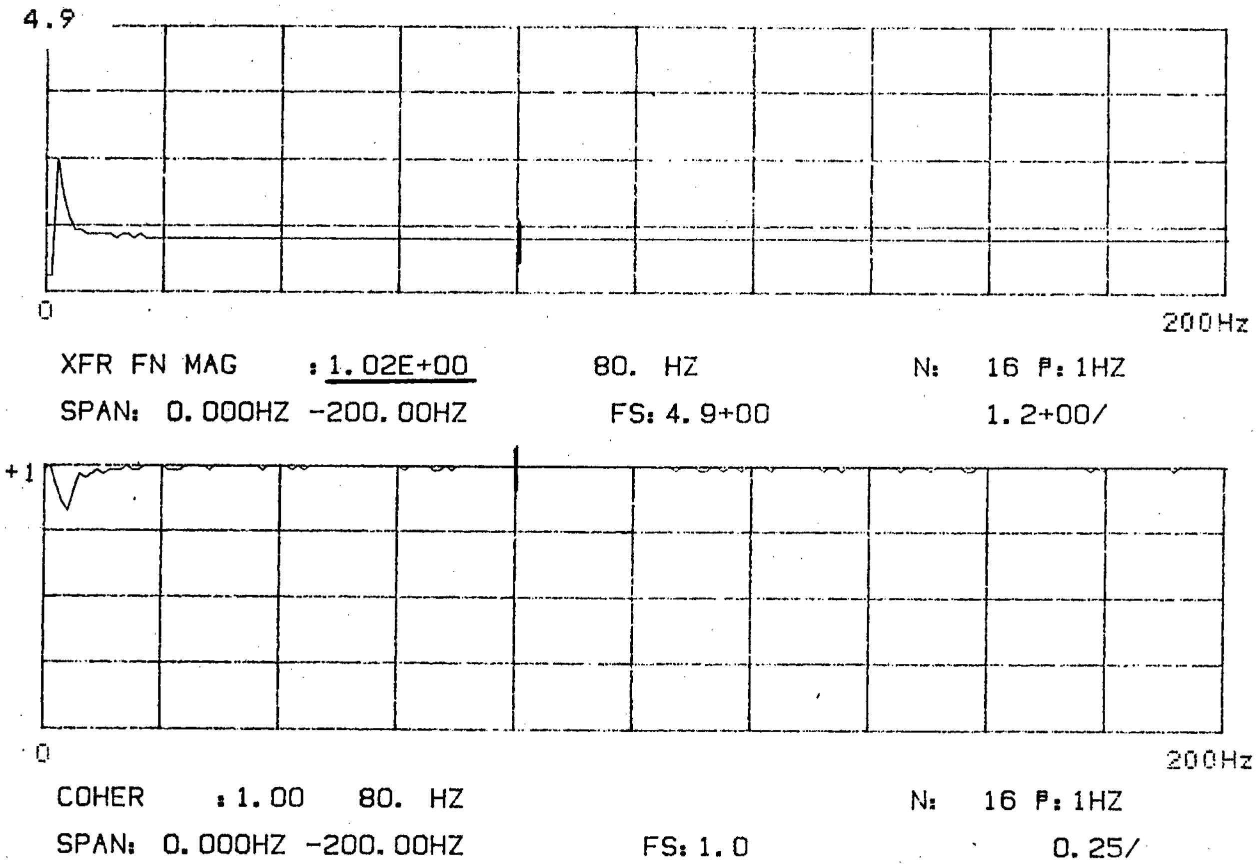


Figure 49. Transfer Function Amplitude and Coherence for PCB SN970 vs Setra

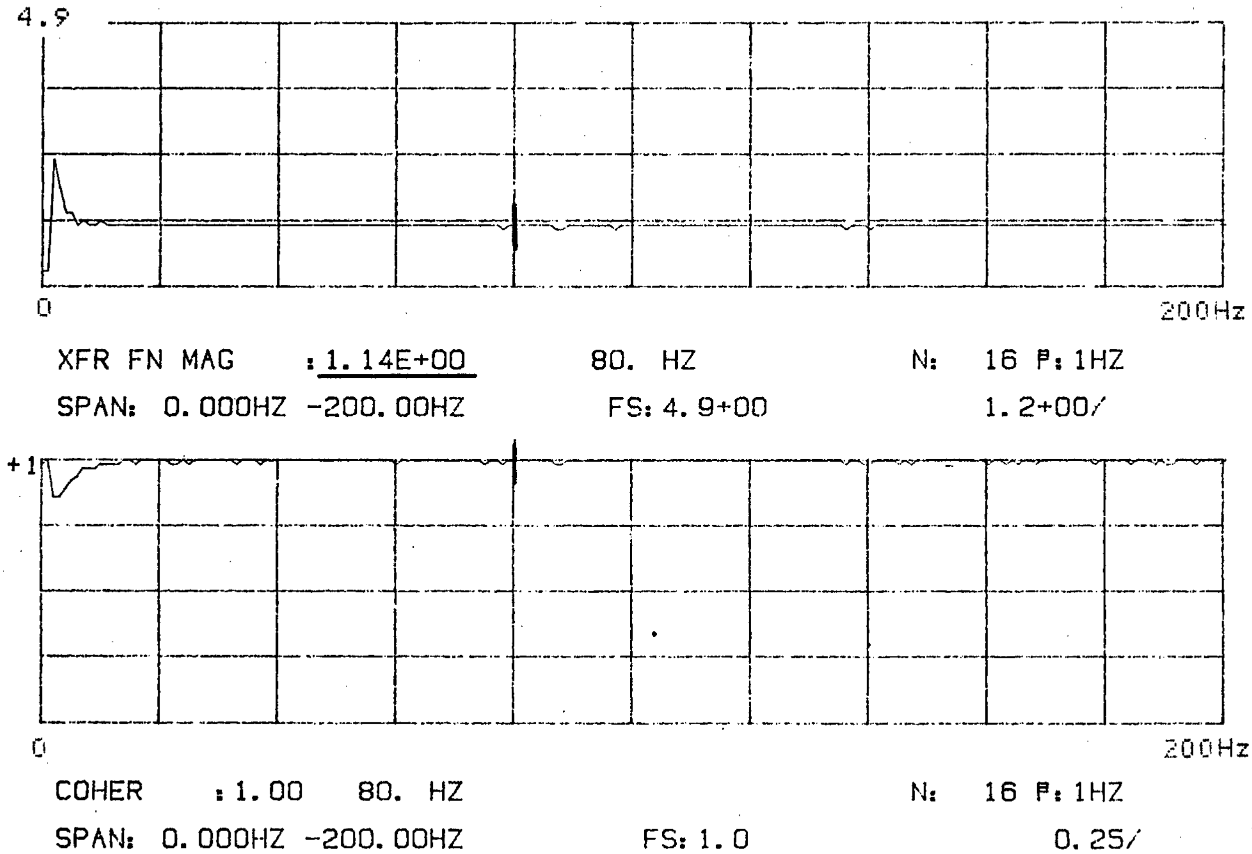
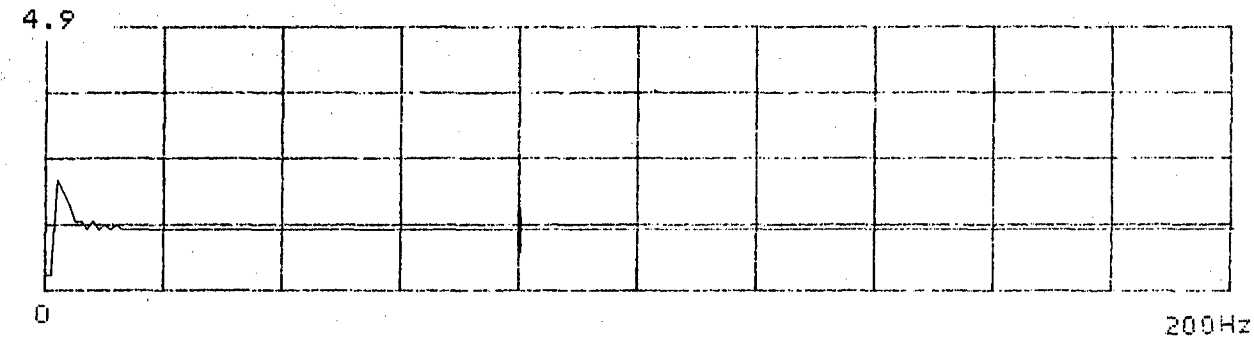
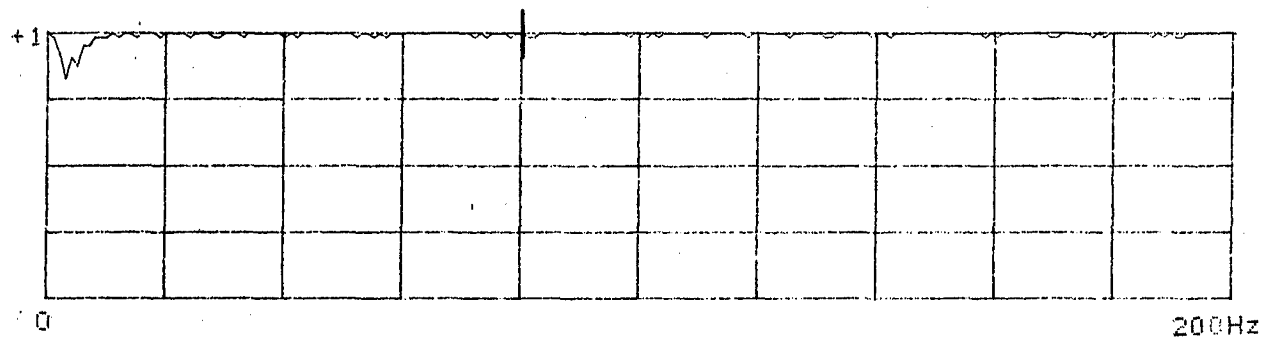


Figure 50. Transfer Function Amplitude and Coherence for PCB SN1134 vs Setra



XFR FN MAG :1.16E+00 80. HZ N: 16 P: 1HZ

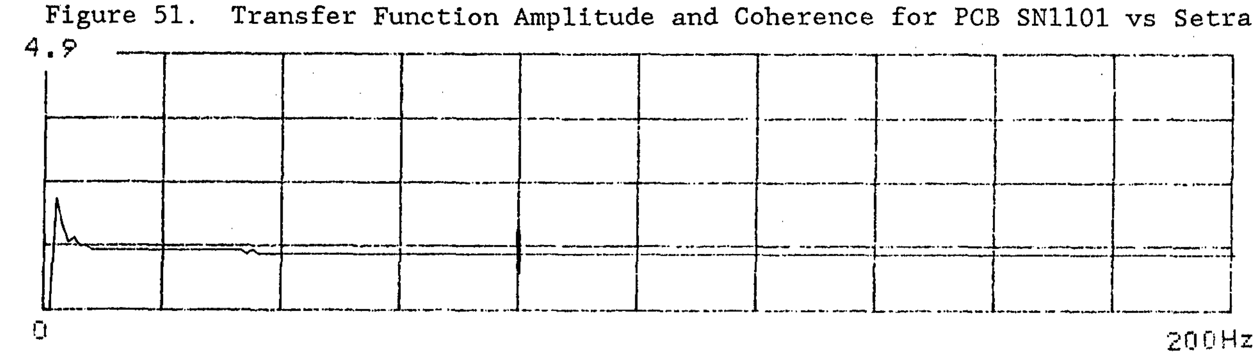
SPAN: 0.000HZ -200.00HZ FS: 4.9+00 1.2+00/



COHER :1.00 80. HZ N: 16 P: 1HZ

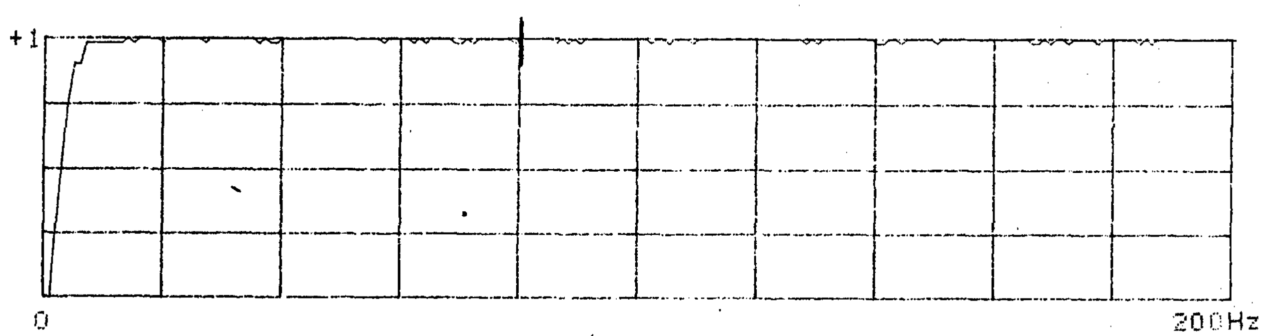
SPAN: 0.000HZ -200.00HZ FS: 1.0 0.25/

Figure 51. Transfer Function Amplitude and Coherence for PCB SN1101 vs Setra



XFR FN MAG :1.11E+00 80. HZ N: 16 P: 1HZ

SPAN: 0.000HZ -200.00HZ FS: 4.9+00 1.2+00/



COHER :1.00 80. HZ N: 16 P: 1HZ

SPAN: 0.000HZ -200.00HZ FS: 1.0 0.25/

Figure 52. Transfer Function Amplitude and Coherence for PCB SN889 vs Setra

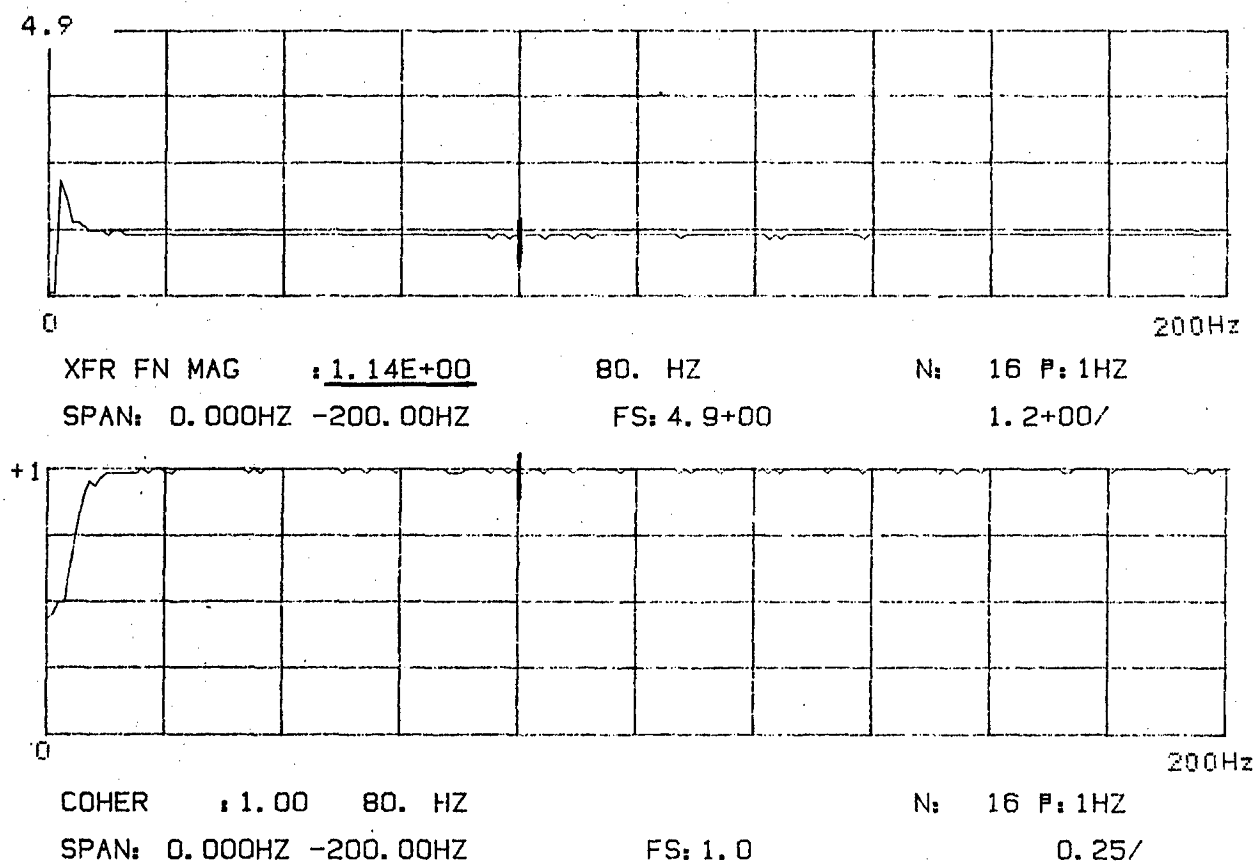


Figure 53. Transfer Function Amplitude and Coherence for PCB SN907 vs Setra

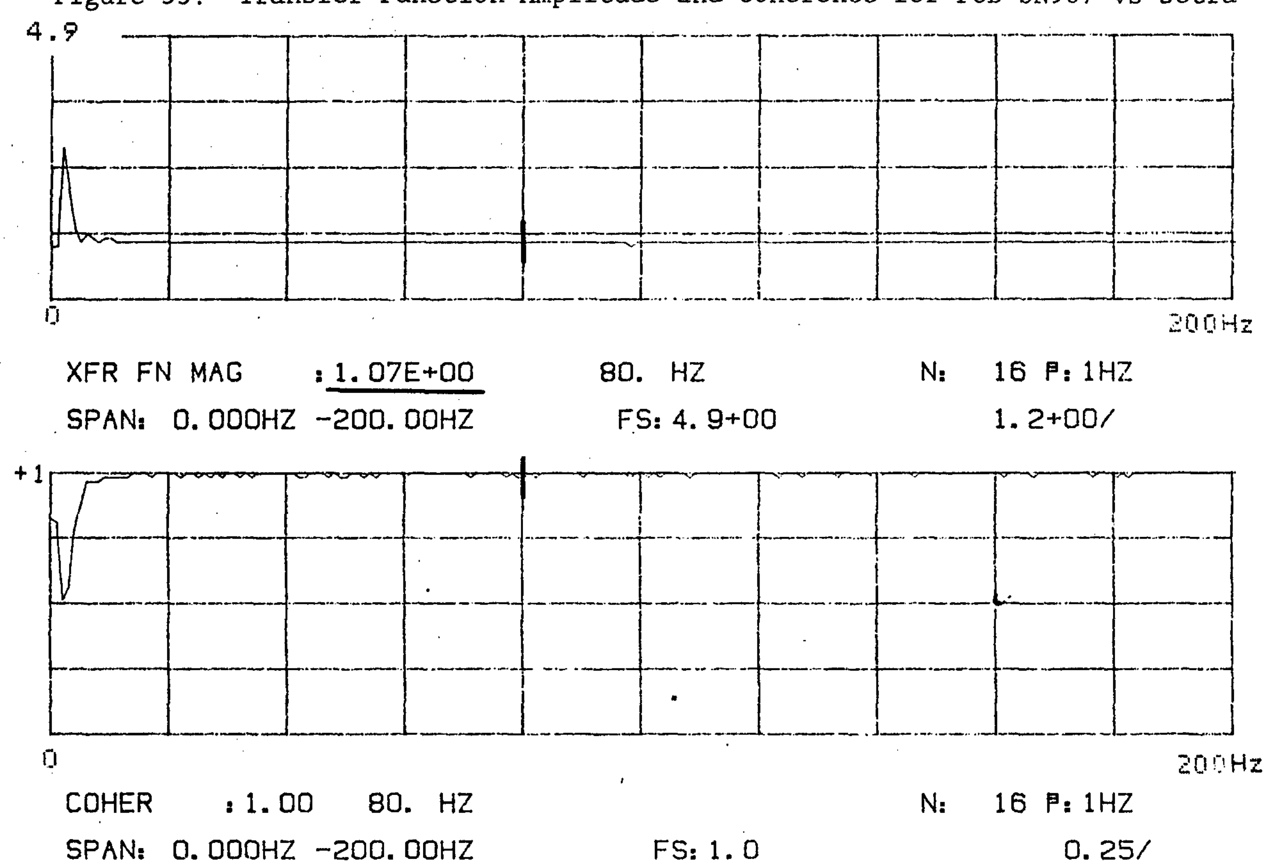


Figure 54. Transfer Function Amplitude and Coherence for PCB SN892 vs Setra

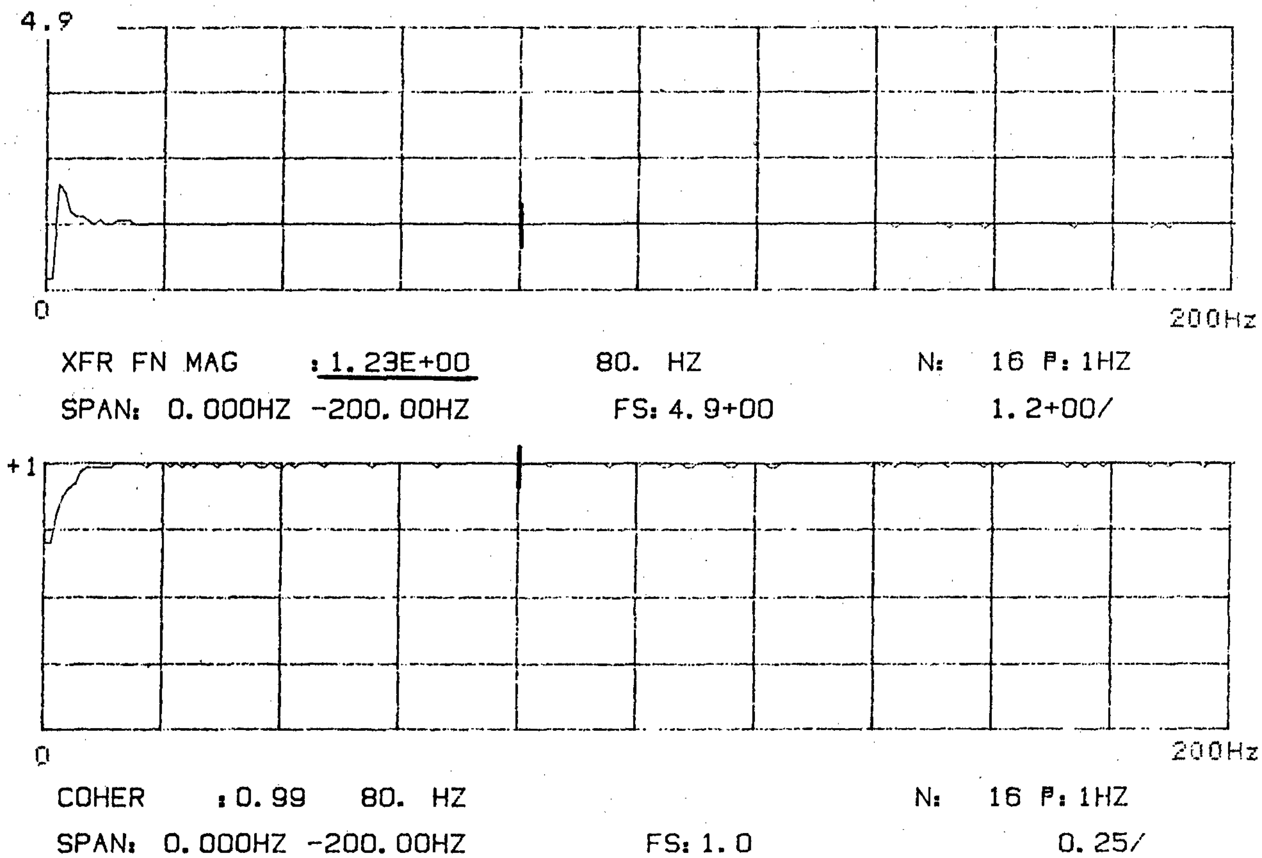


Figure 55. Transfer Function Amplitude and Coherence for PCB SN841 vs Setra

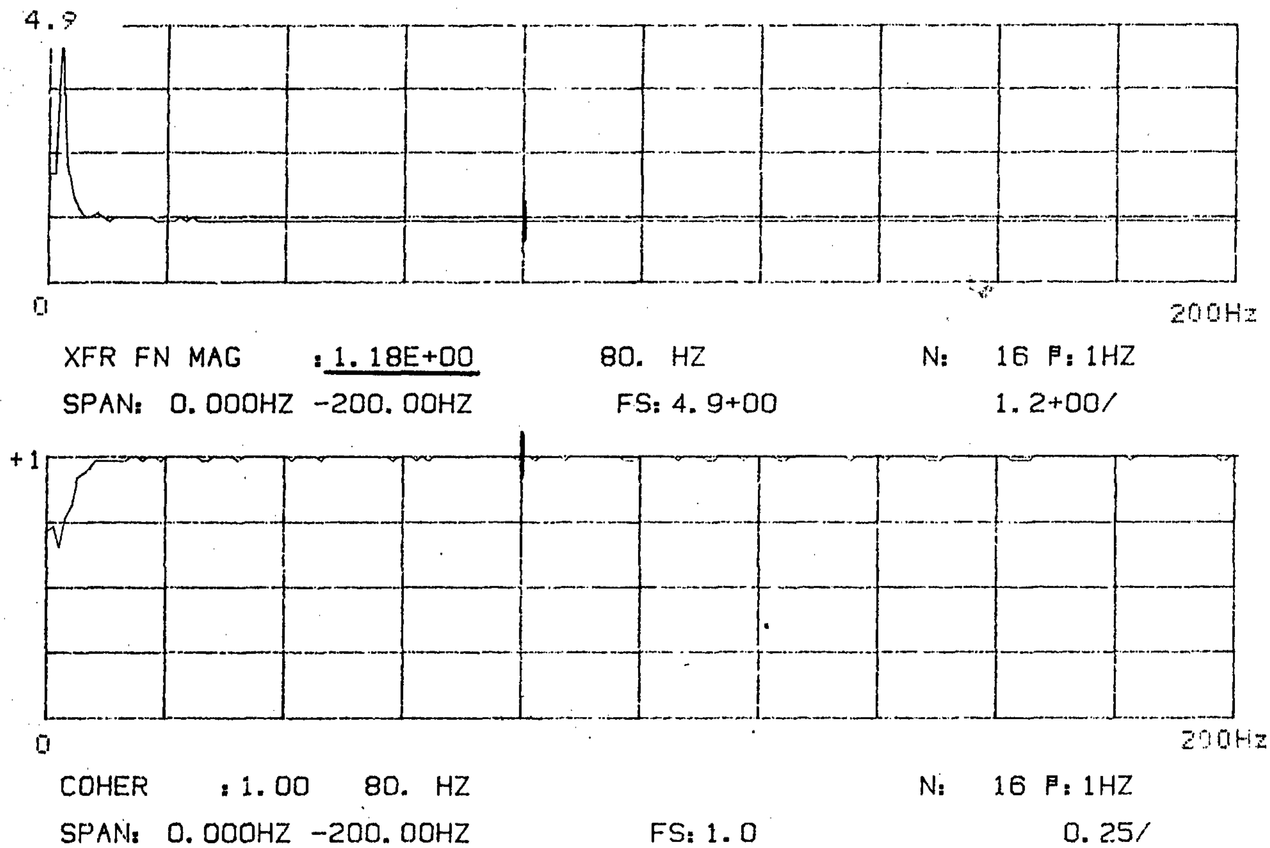


Figure 56. Transfer Function Amplitude and Coherence for PCB SN546 vs Setra

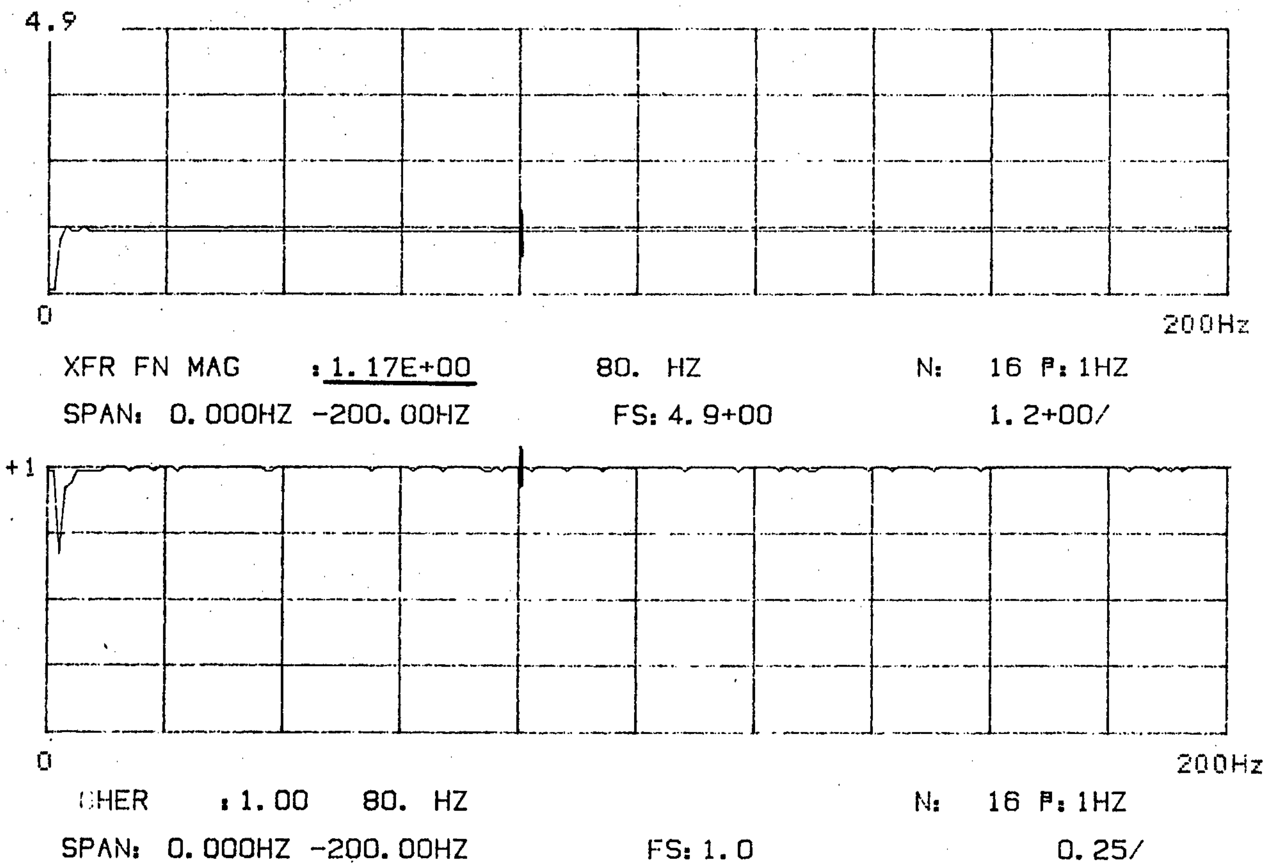


Figure 57. Transfer Function Amplitude and Coherence for PCB SN818 vs Setra

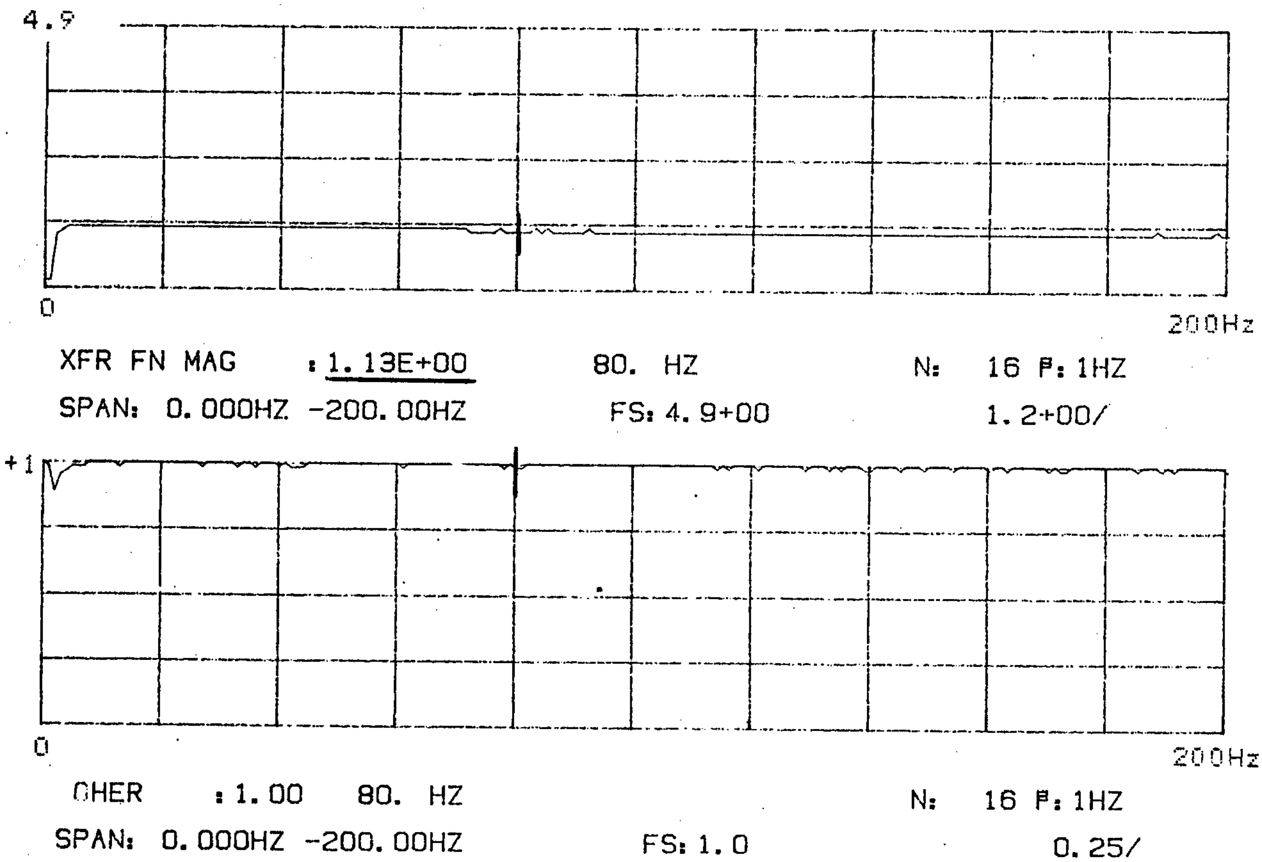
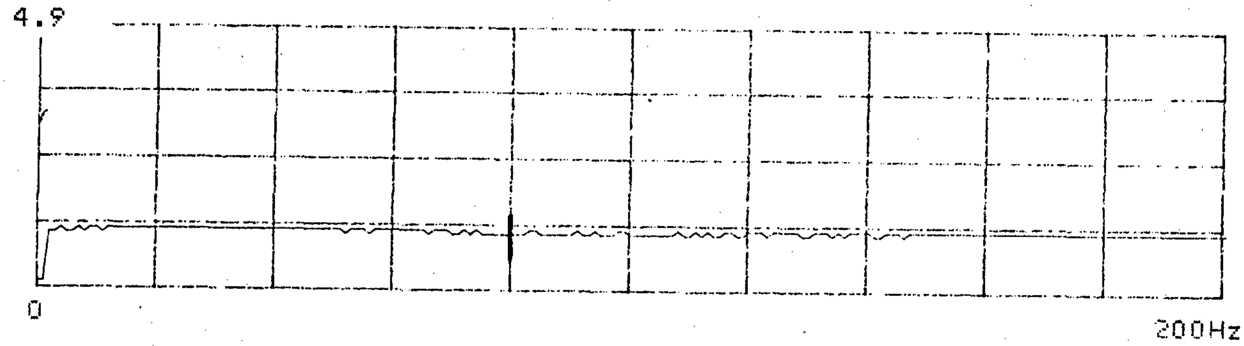
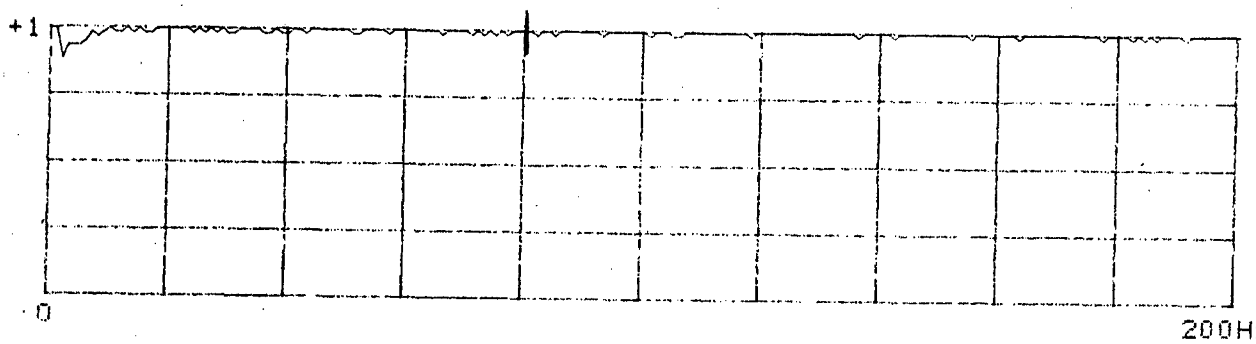


Figure 58. Transfer Function Amplitude and Coherence for PCB SN867 vs Setra



XFR FN MAG : 1.13E+00 80. HZ N: 16 P: 1HZ

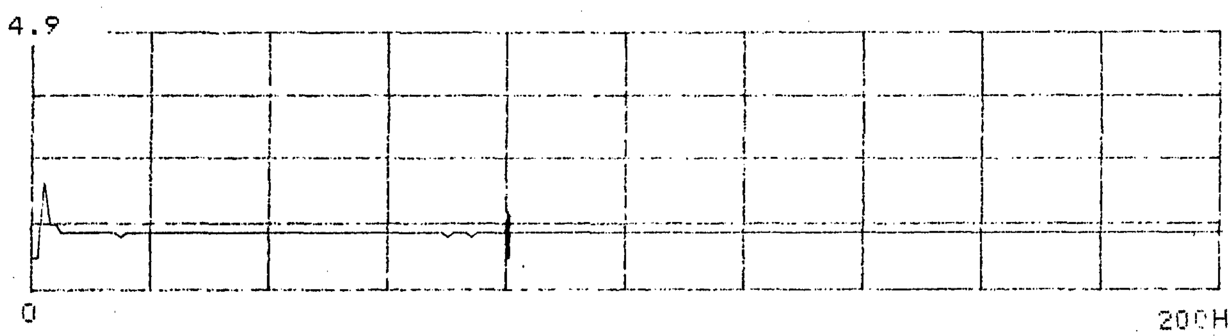
SPAN: 0.000HZ -200.00HZ FS: 4.9+00 1.2+00/



COHER : 1.00 80. HZ N: 16 P: 1HZ

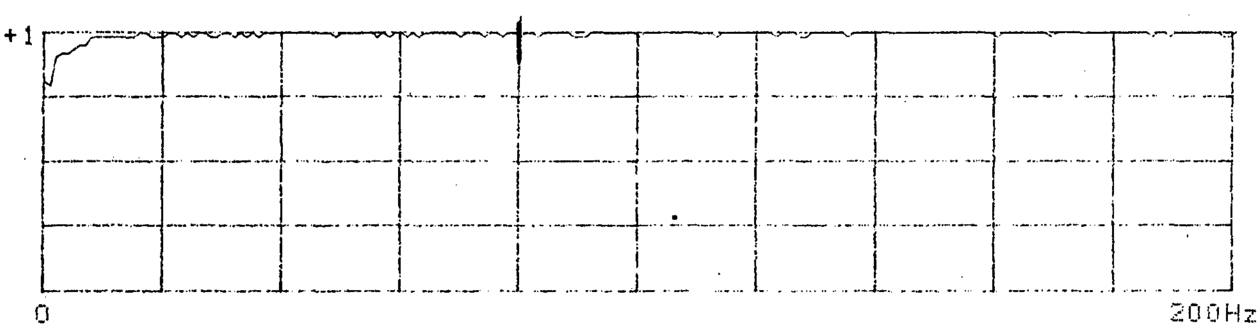
SPAN: 0.000HZ -200.00HZ FS: 1.0 0.25/

Figure 59. Transfer Function Amplitude and Coherence for PCB SN1139 vs Setra



XFR FN MAG : 1.06E+00 80. HZ N: 16 P: 1HZ

SPAN: 0.000HZ -200.00HZ FS: 4.9+00 1.2+00/



COHER : 0.99 80. HZ N: 16 P: 1HZ

SPAN: 0.000HZ -200.00HZ FS: 1.0 0.25/

Figure 60. Transfer Function Amplitude and Coherence for PCB SN1153 vs Setra

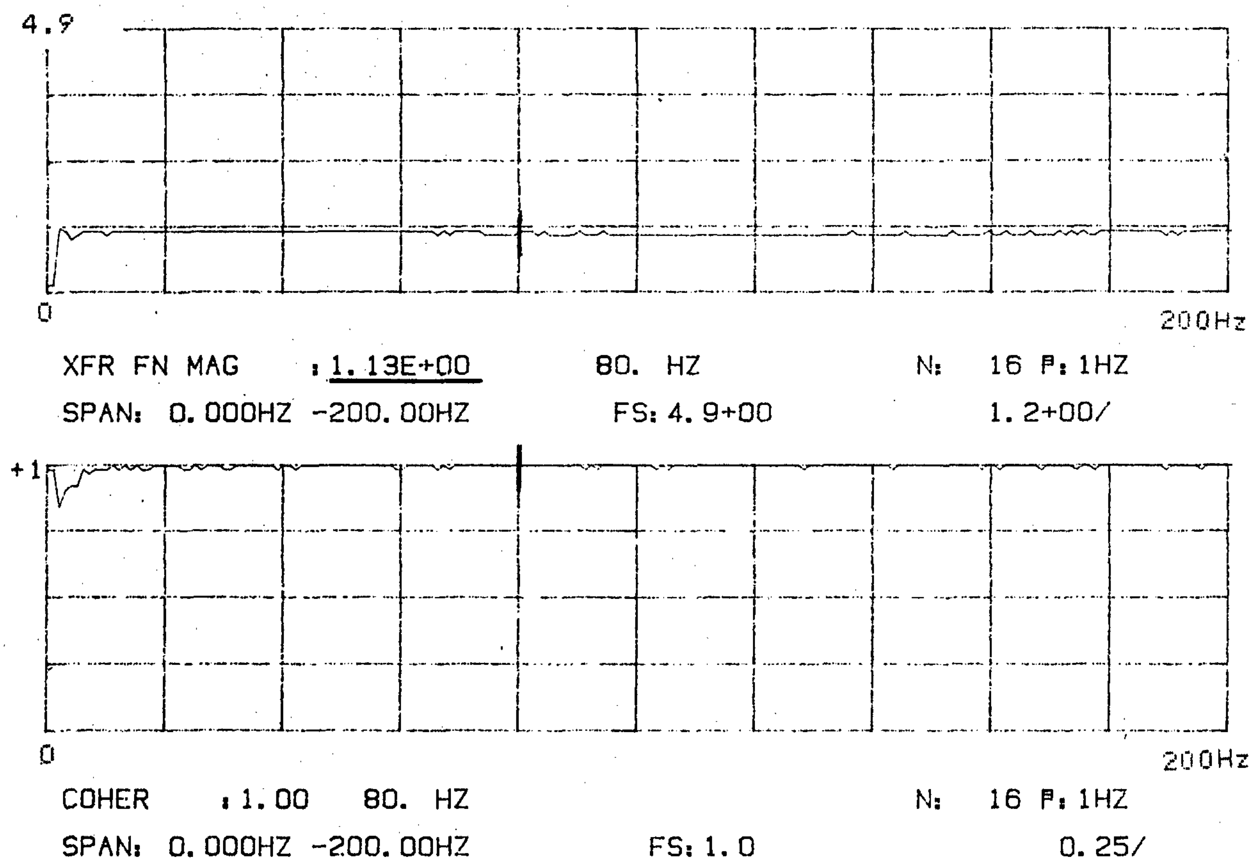


Figure 61. Transfer Function Amplitude and Coherence for PCB SN1170 vs Setra

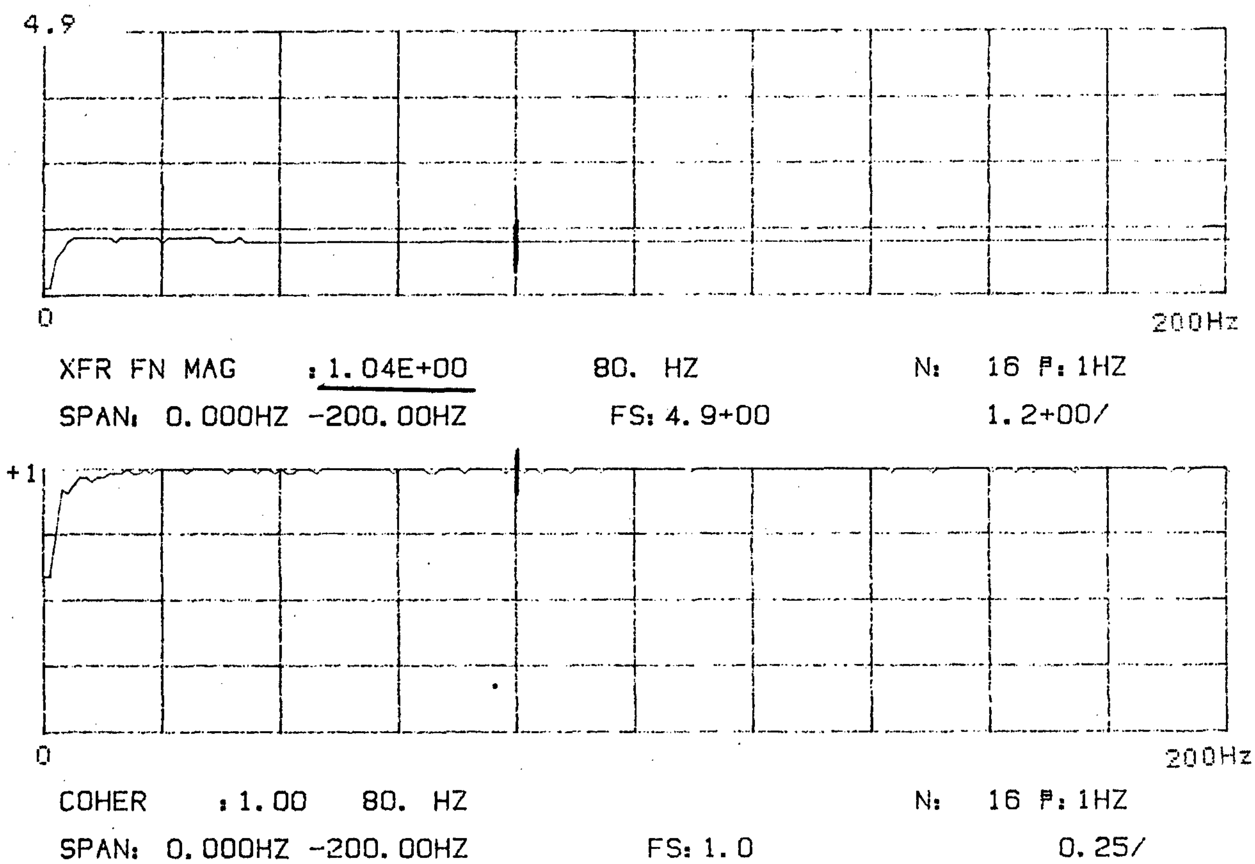


Figure 62. Transfer Function Amplitude and Coherence for PCB SN1174 vs Setra

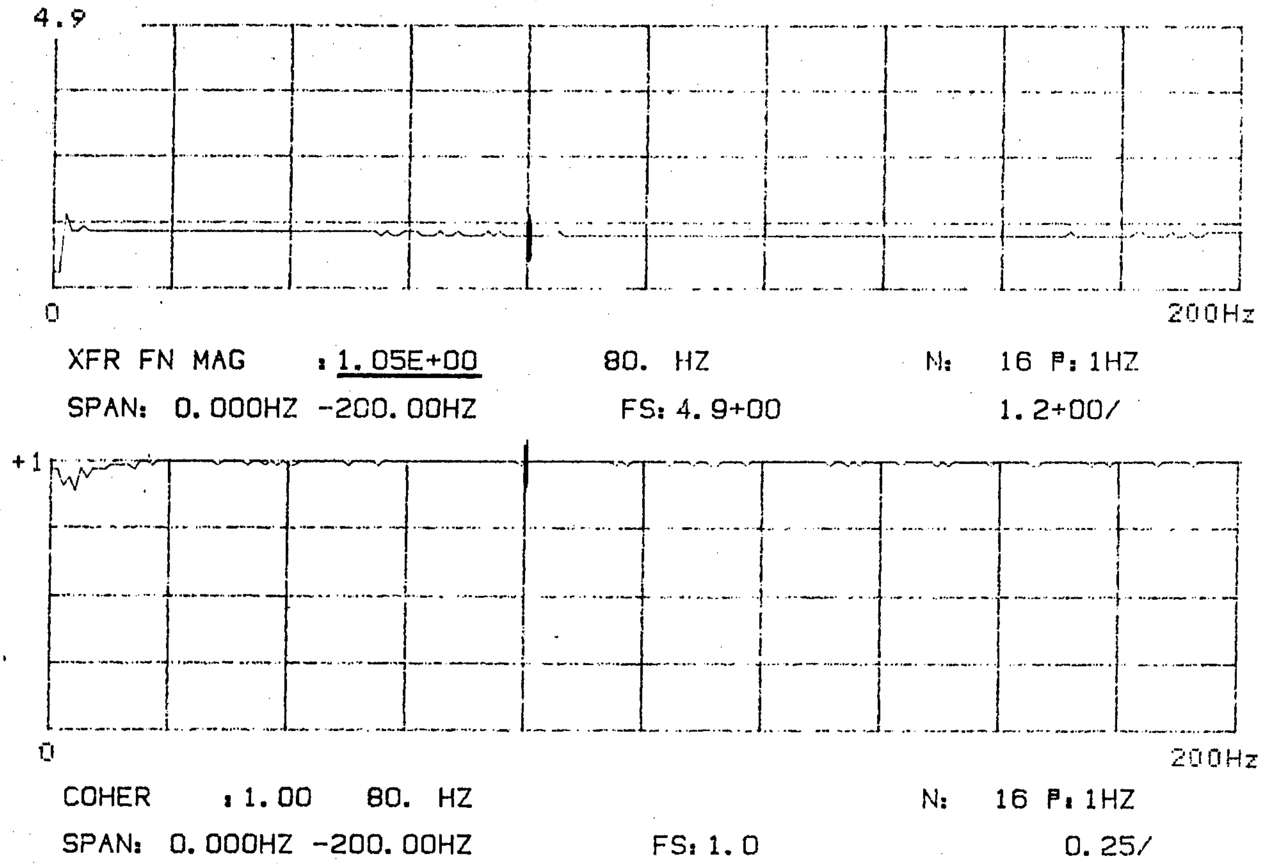


Figure 63. Transfer Function Amplitude and Coherence for PCB SN1193 vs Setra

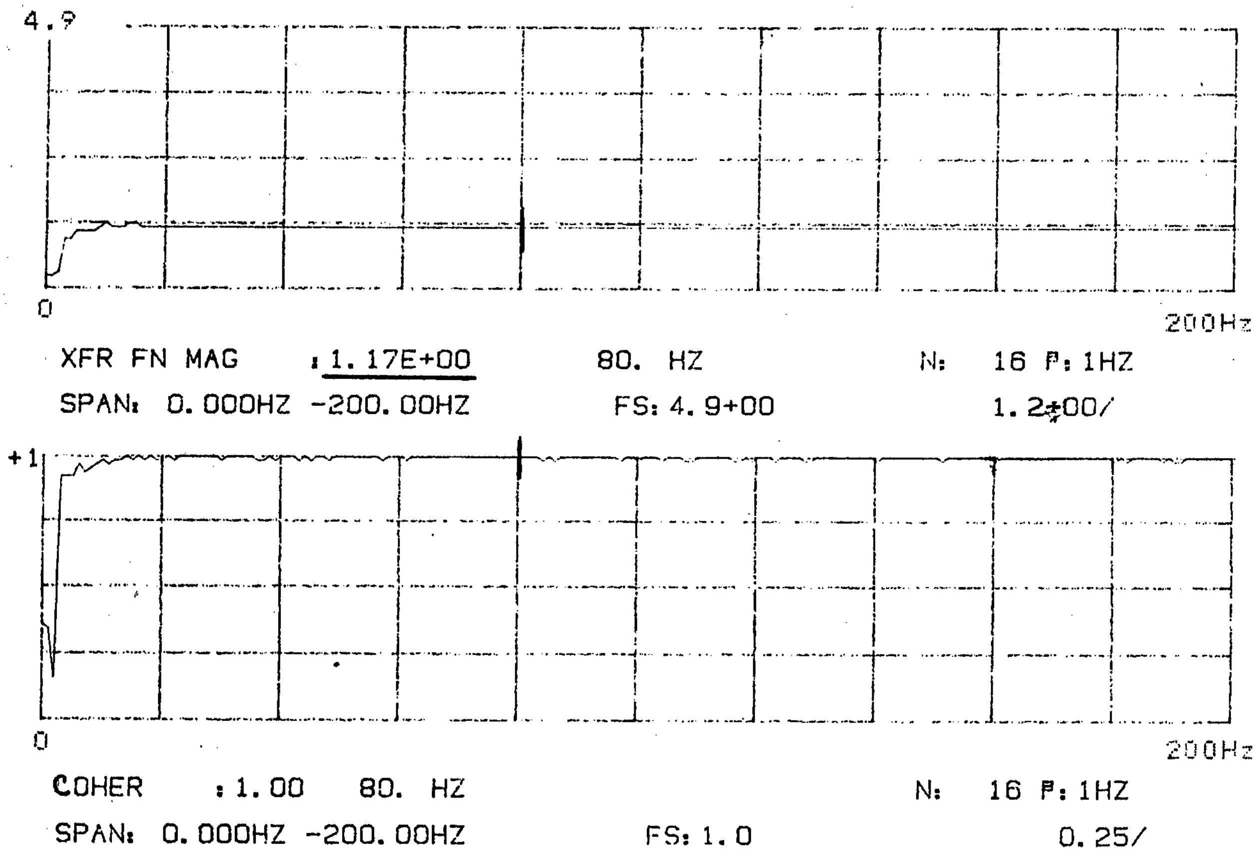


Figure 64. Transfer Function Amplitude and Coherence for PCB SN1208 vs Setra

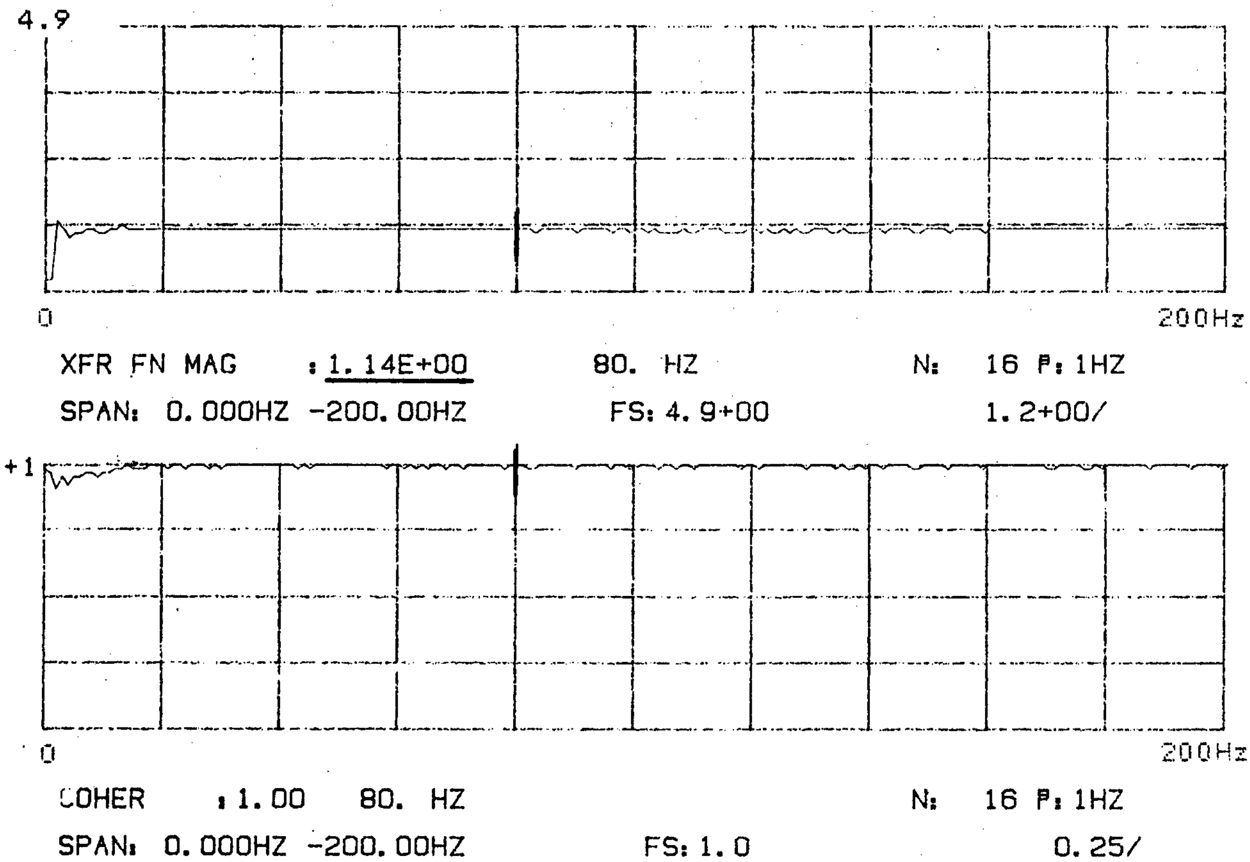


Figure 65. Transfer Function Amplitude and Coherence for PCB SN1210 vs Setra

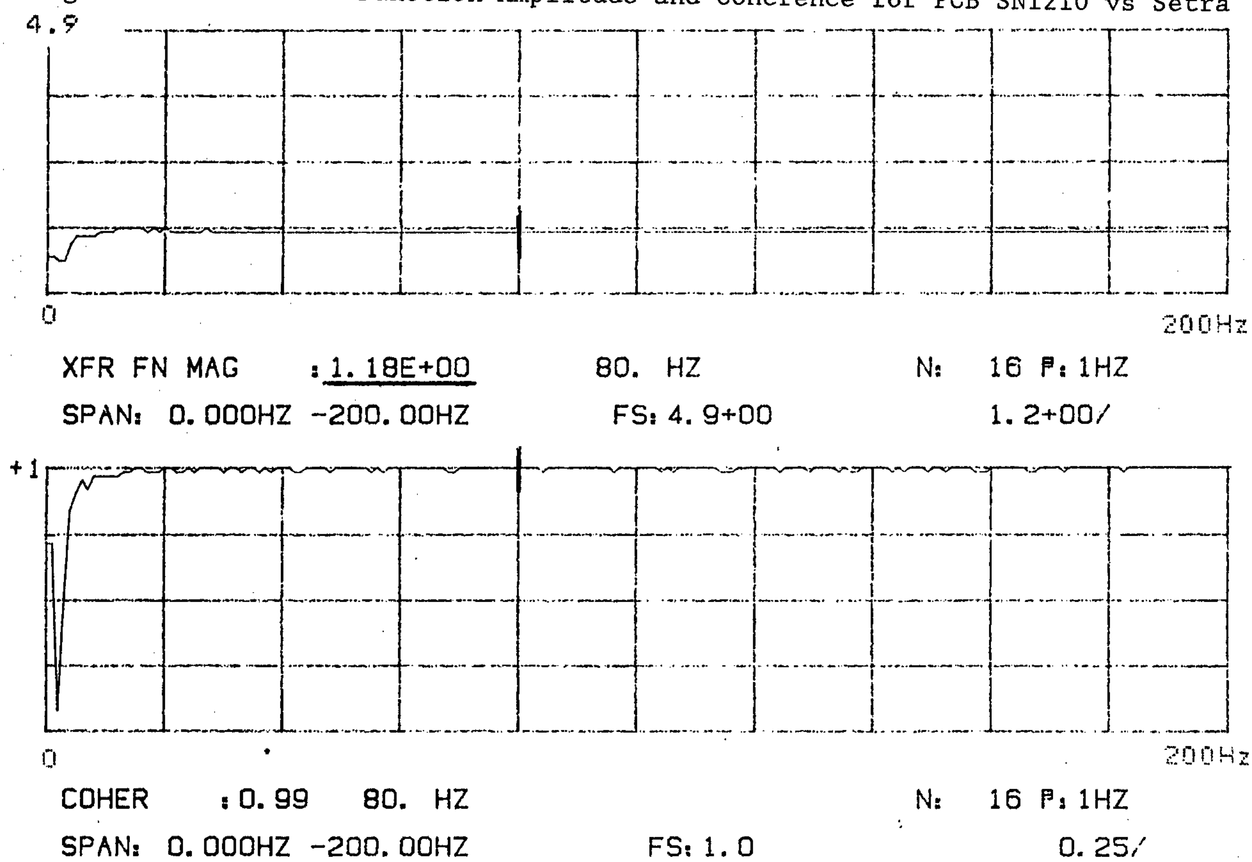


Figure 66. Transfer Function Amplitude and Coherence for PCB SN1212 vs Setra

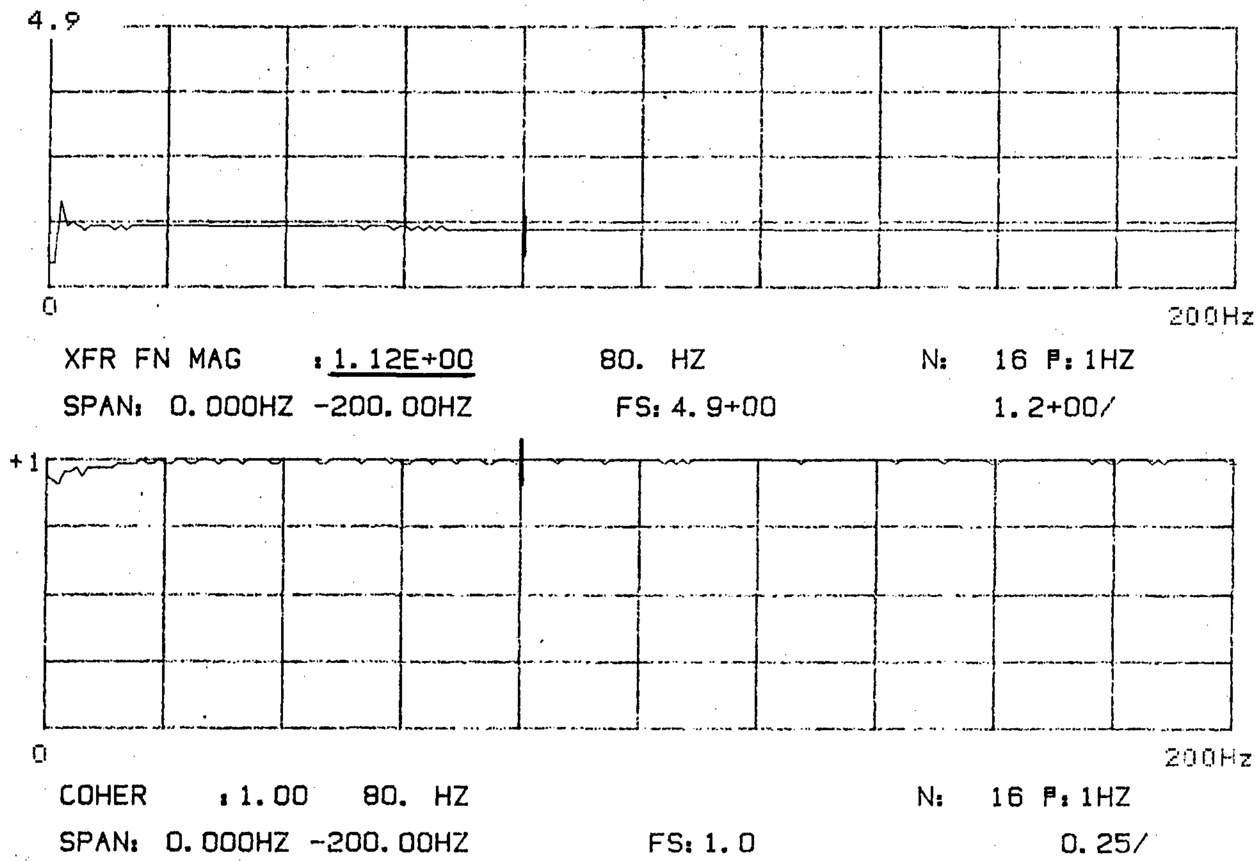


Figure 67. Transfer Function Amplitude and Coherence for PCB SN1213 vs Setra

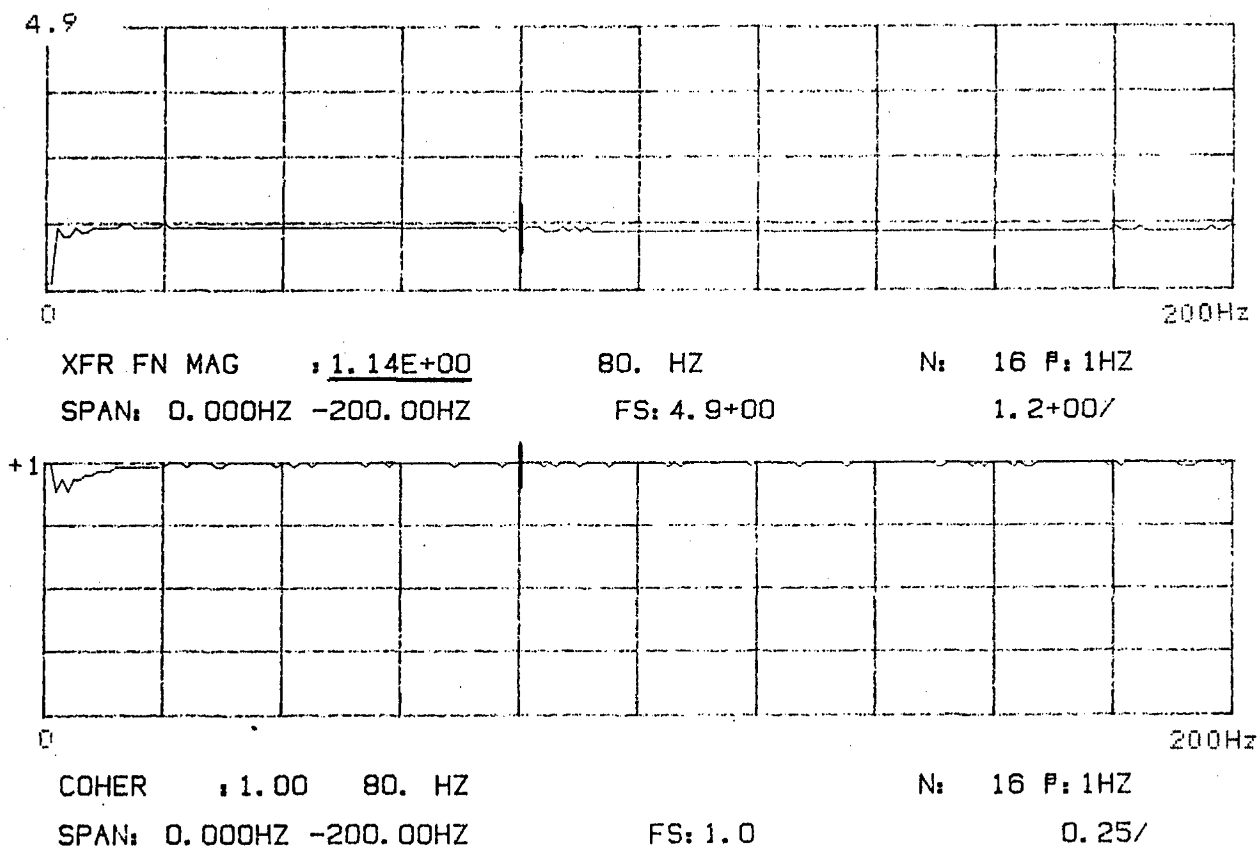


Figure 68. Transfer Function Amplitude and Coherence for PCB SN1215 vs Setra

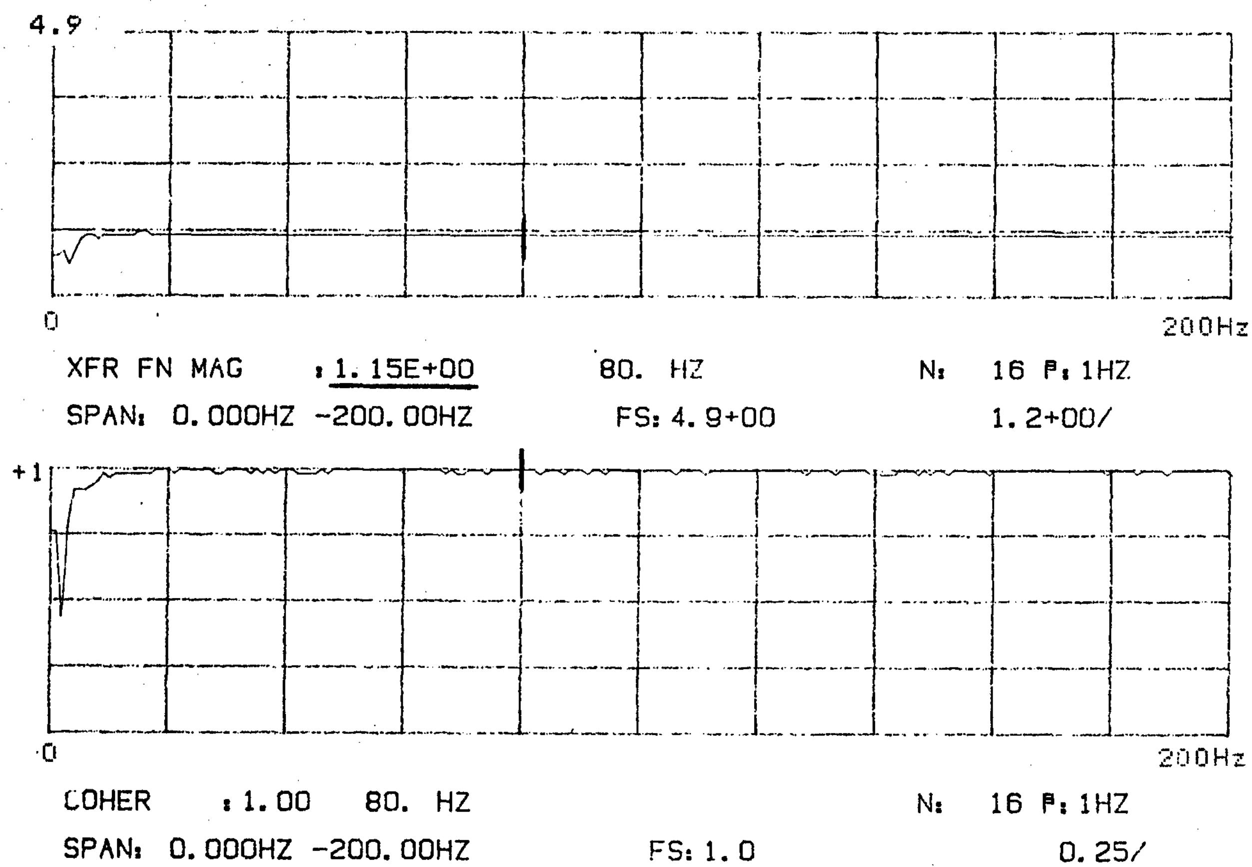


Figure 69. Transfer Function Amplitude and Coherence for PCB SN1218 vs Setra

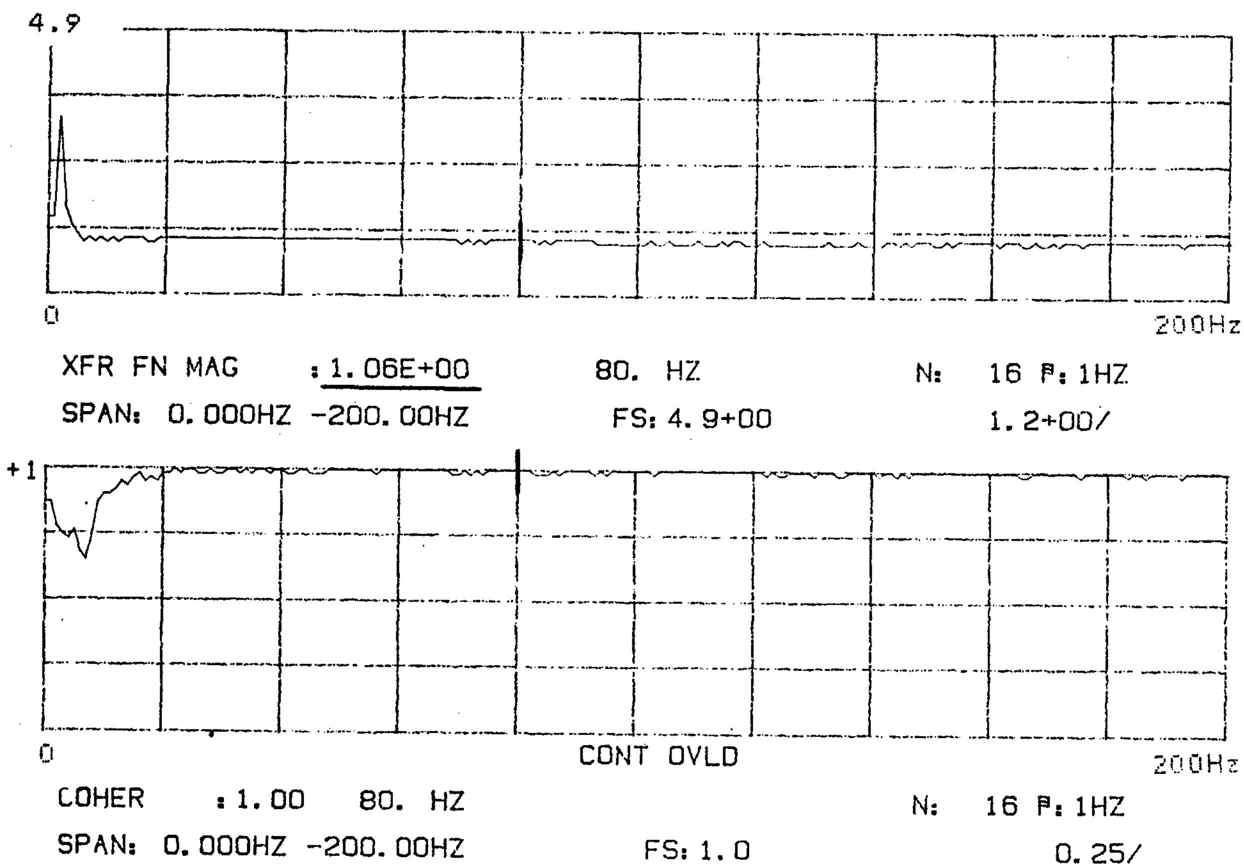


Figure 70. Transfer Function Amplitude and Coherence for PCB SN1219 vs Setra

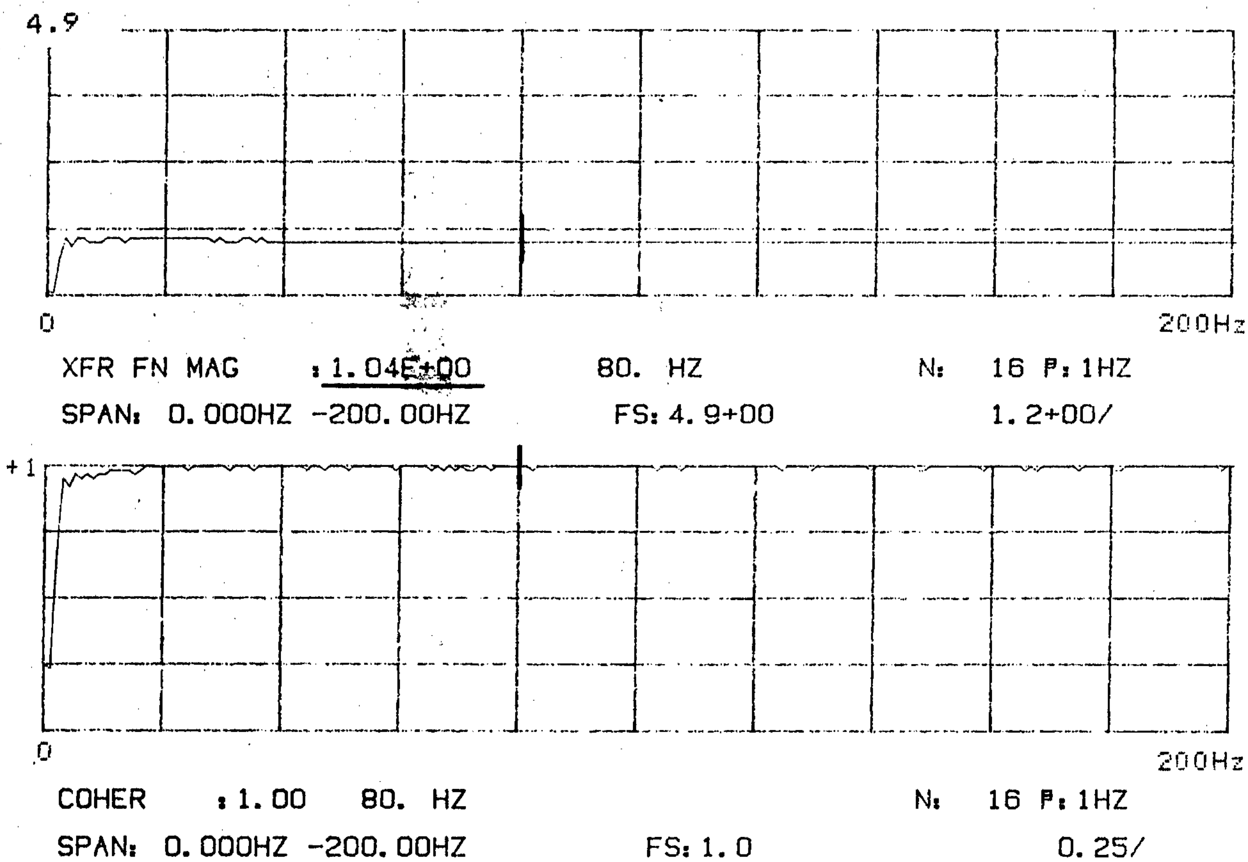


Figure 71. Transfer Function Amplitude and Coherence for PCB SN1234 vs Setra

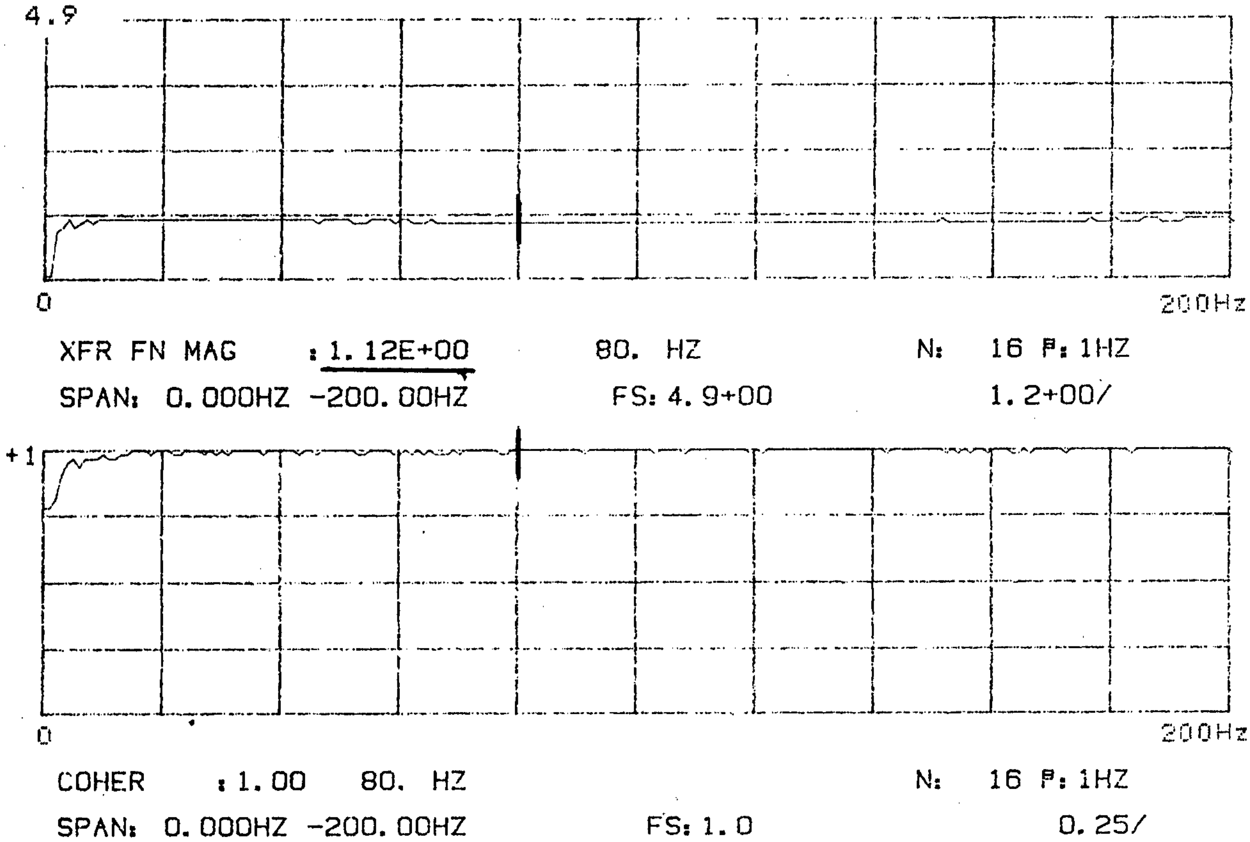


Figure 72. Transfer Function Amplitude and Coherence for PCB SN1237 vs Setra

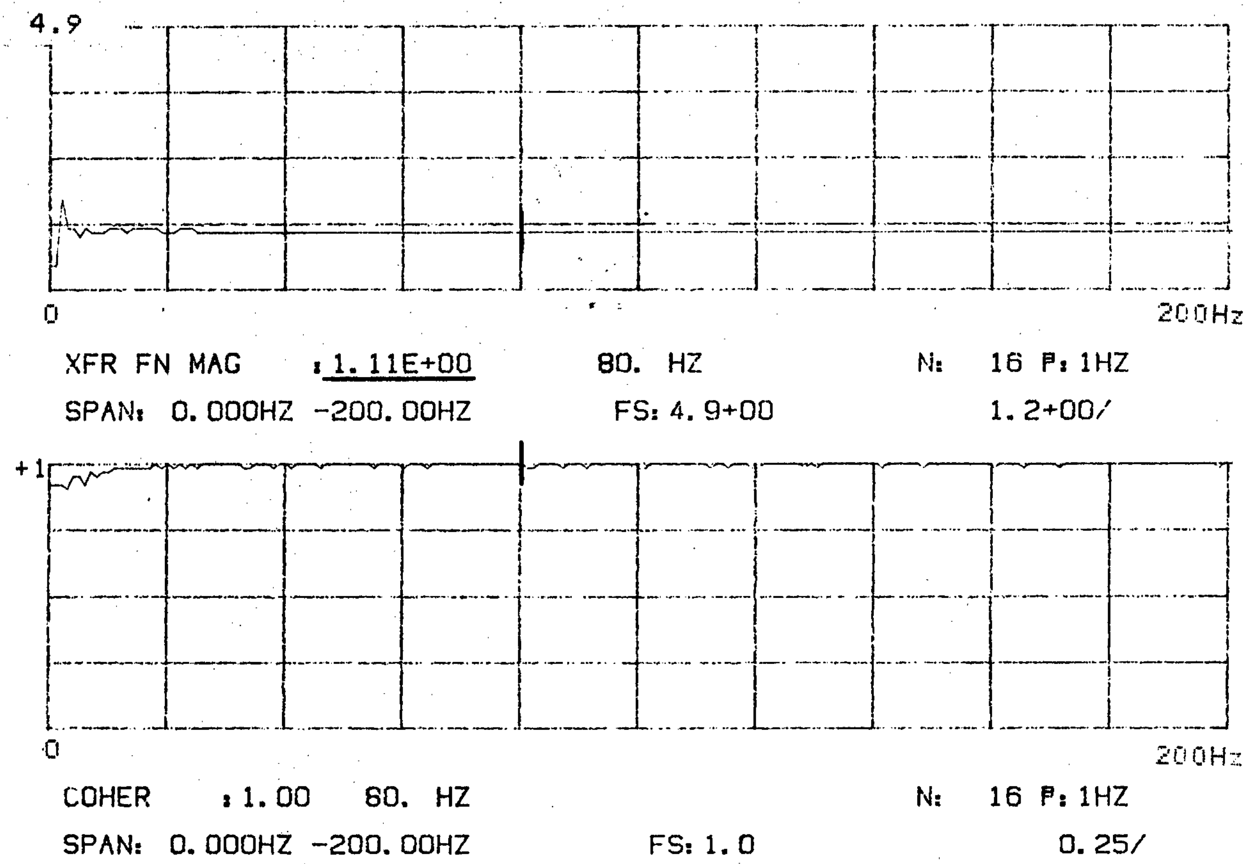


Figure 73. Transfer Function Amplitude and Coherence for PCB SN1242 vs Setra

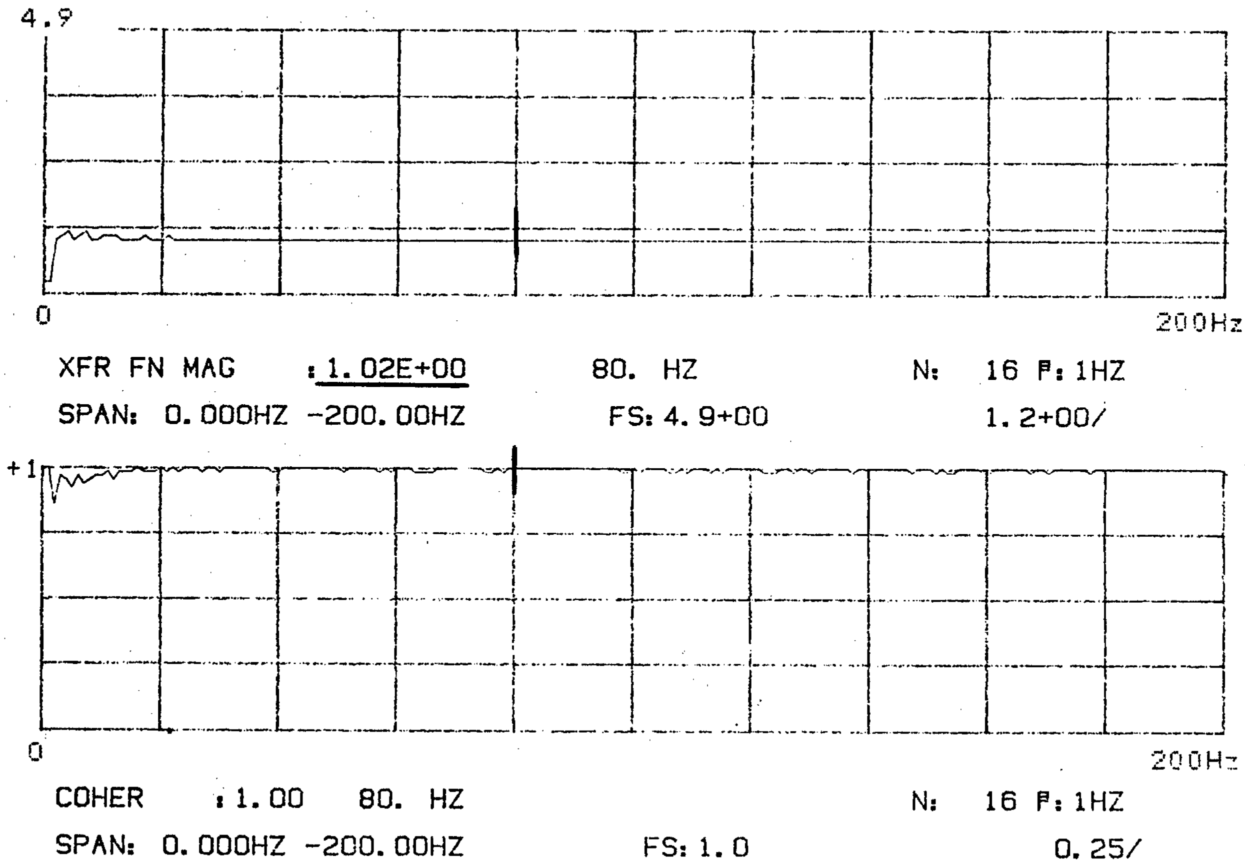
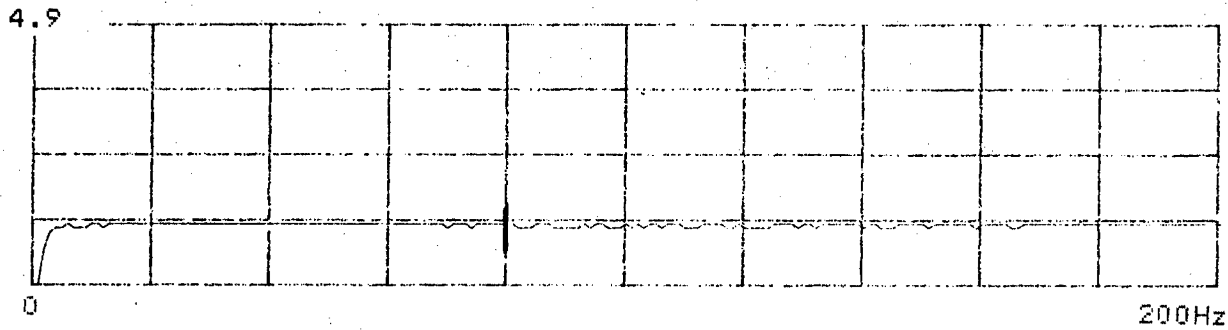


Figure 74. Transfer Function Amplitude and Coherence for PCB SN1243 vs Setra



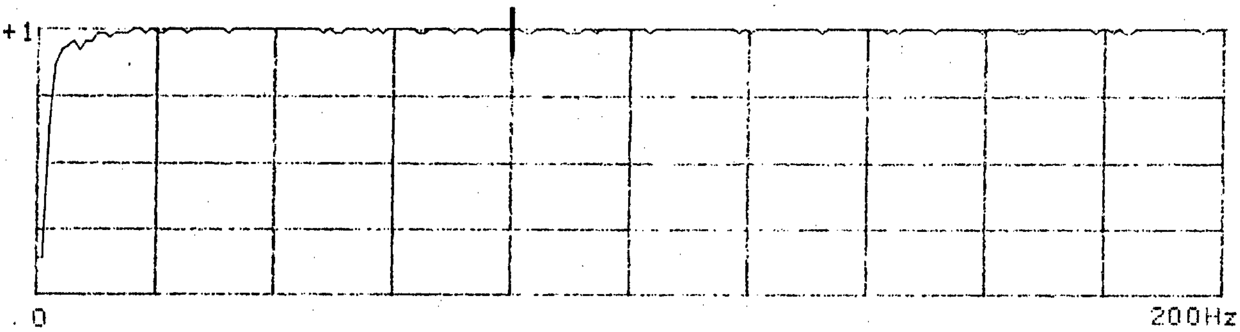
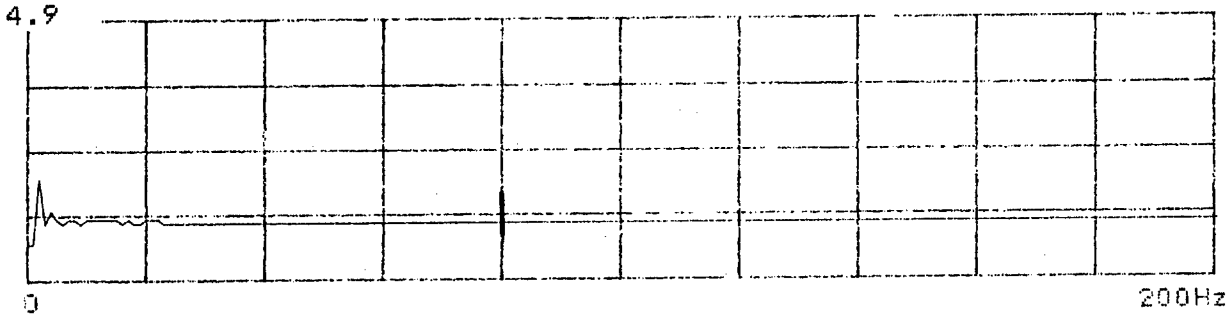


Figure 75. Transfer Function Amplitude and Coherence for PCB SN1247 vs Setra



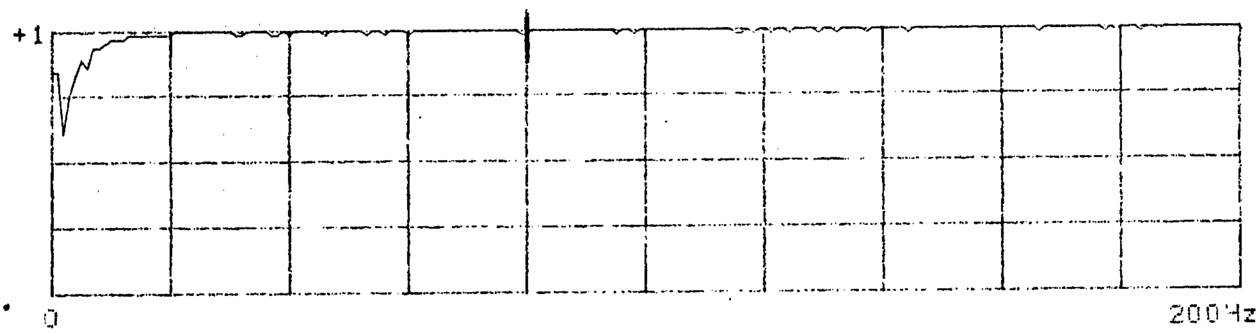
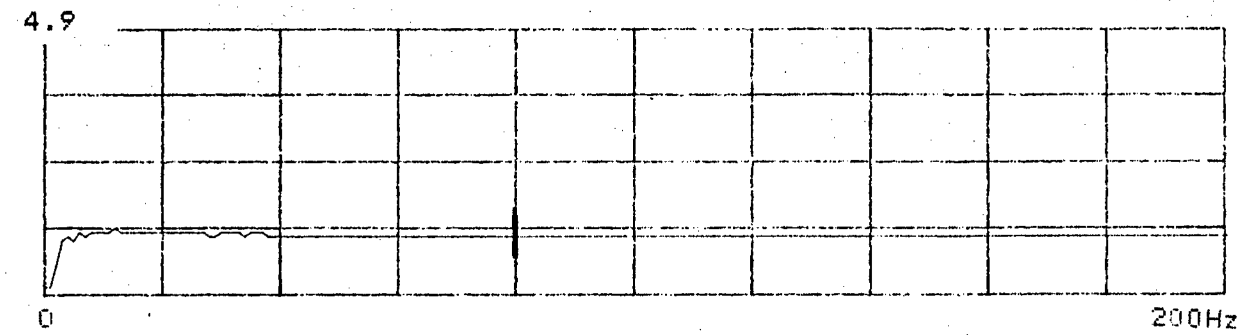
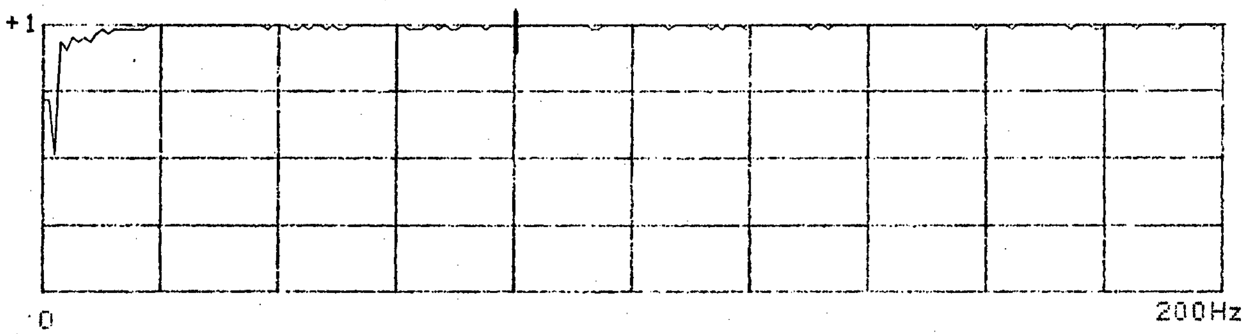


Figure 76. Transfer Function Amplitude and Coherence for PCB SN1249 vs Setra



XFR FN MAG : 1.11E+00 80. HZ N: 16 F: 1HZ

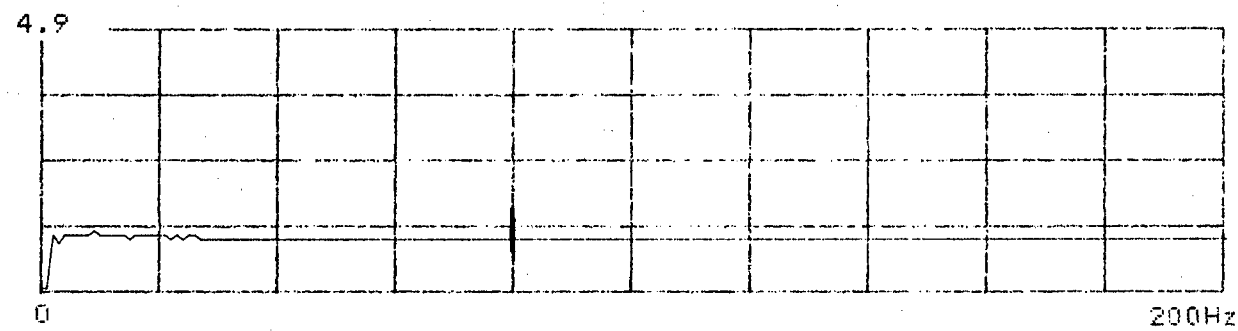
SPAN: 0.000HZ -200.00HZ FS: 4.9+00 1.2+00/



COHER : 1.00 80. HZ N: 16 F: 1HZ

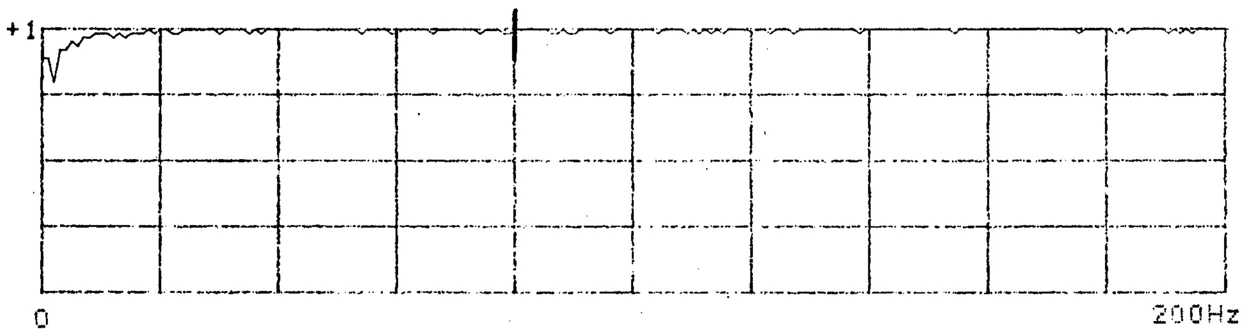
SPAN: 0.000HZ -200.00HZ FS: 1.0 0.25/

Figure 77. Transfer Function Amplitude and Coherence for PCB SN1255 vs Setra



XFR FN MAG : 1.04E+00 80. HZ N: 16 F: 1HZ

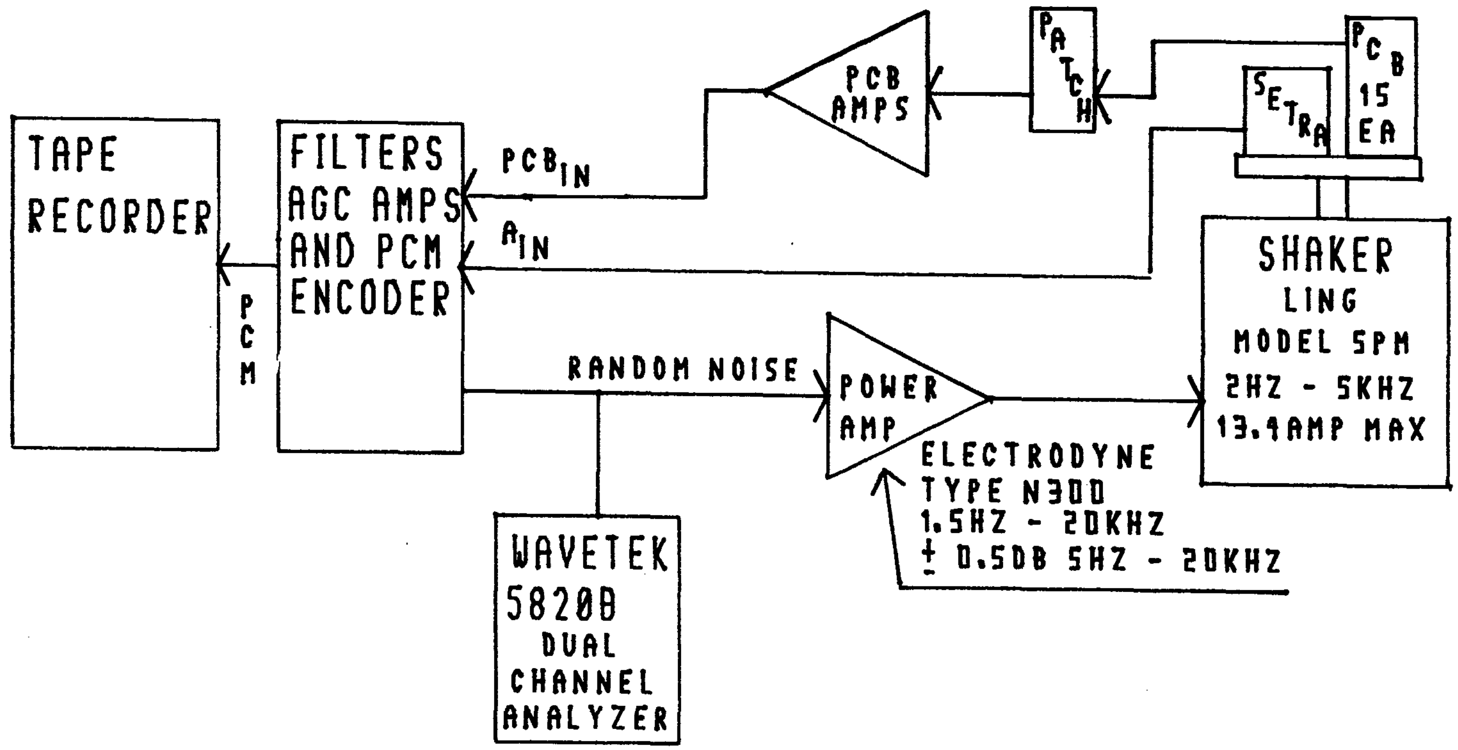
SPAN: 0.000HZ -200.00HZ FS: 4.9+00 1.2+00/



COHER : 1.00 80. HZ N: 16 F: 1HZ

SPAN: 0.000HZ -200.00HZ FS: 1.0 0.25/

Figure 78. Transfer Function Amplitude and Coherence for PCB SN1258 vs Setra



CASE 1) PCB(B_{IN}) vs Setra (A_N - 49mv/g) For DC-200Hz

Setra 141A S/N120511 49.5mv/g 3 point Cal Fluke 10-6-86

Figure 79. Block Diagram of Laboratory Pretest Calibration

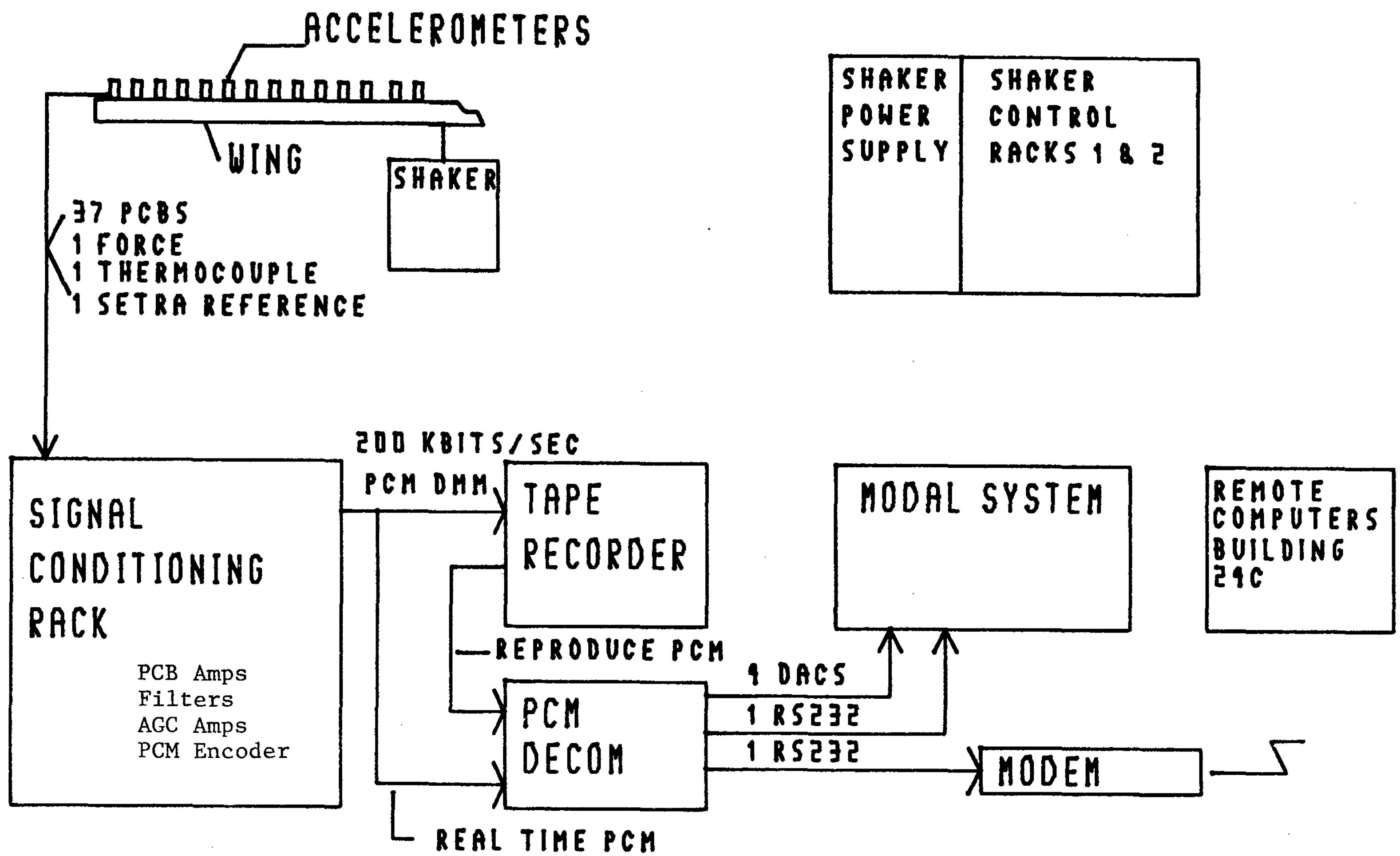
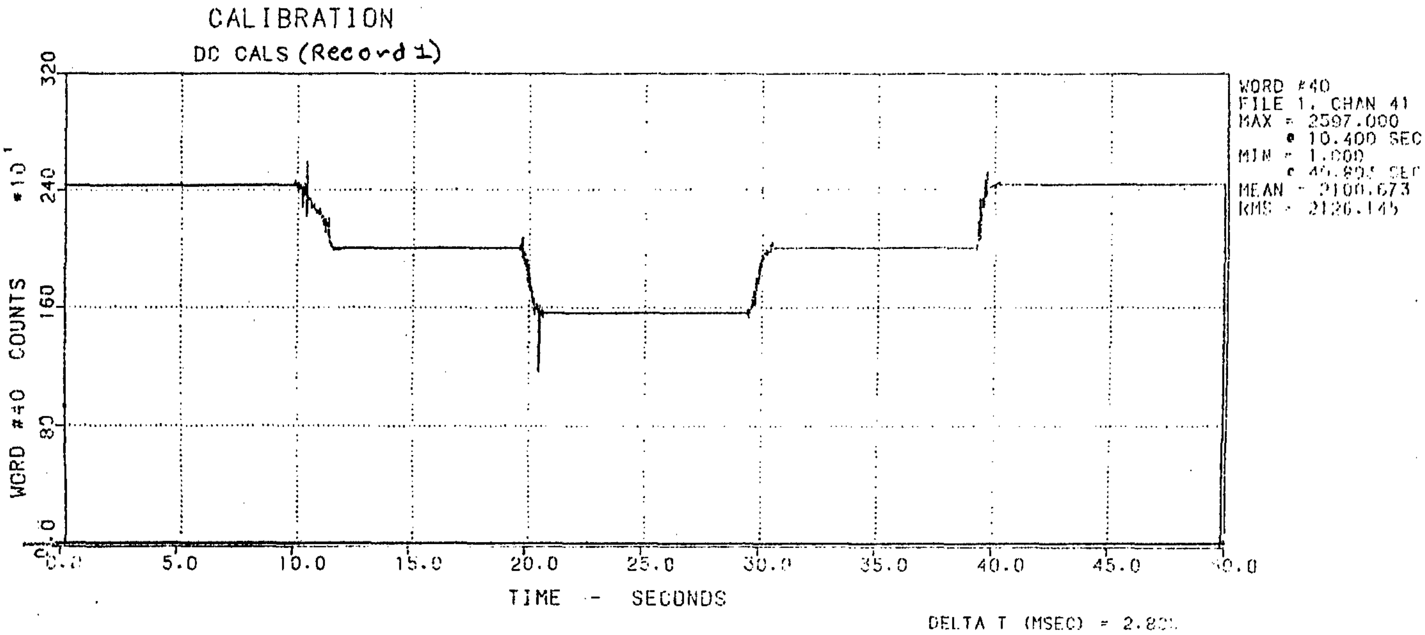
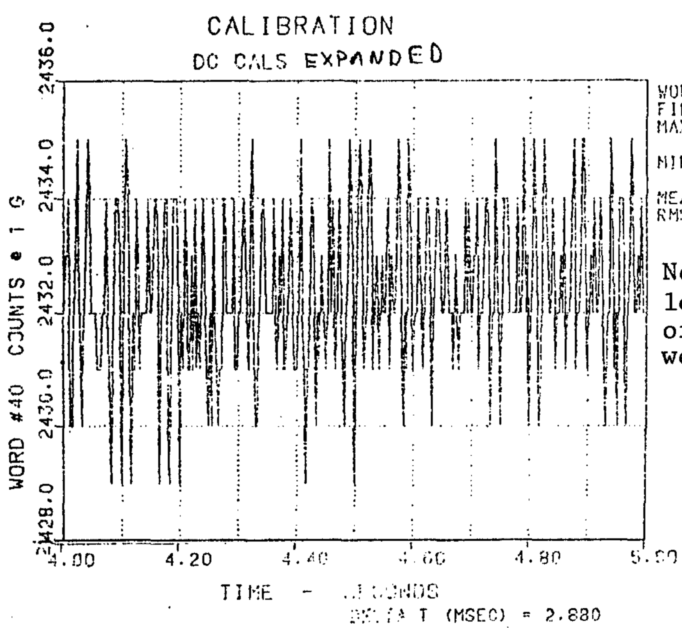


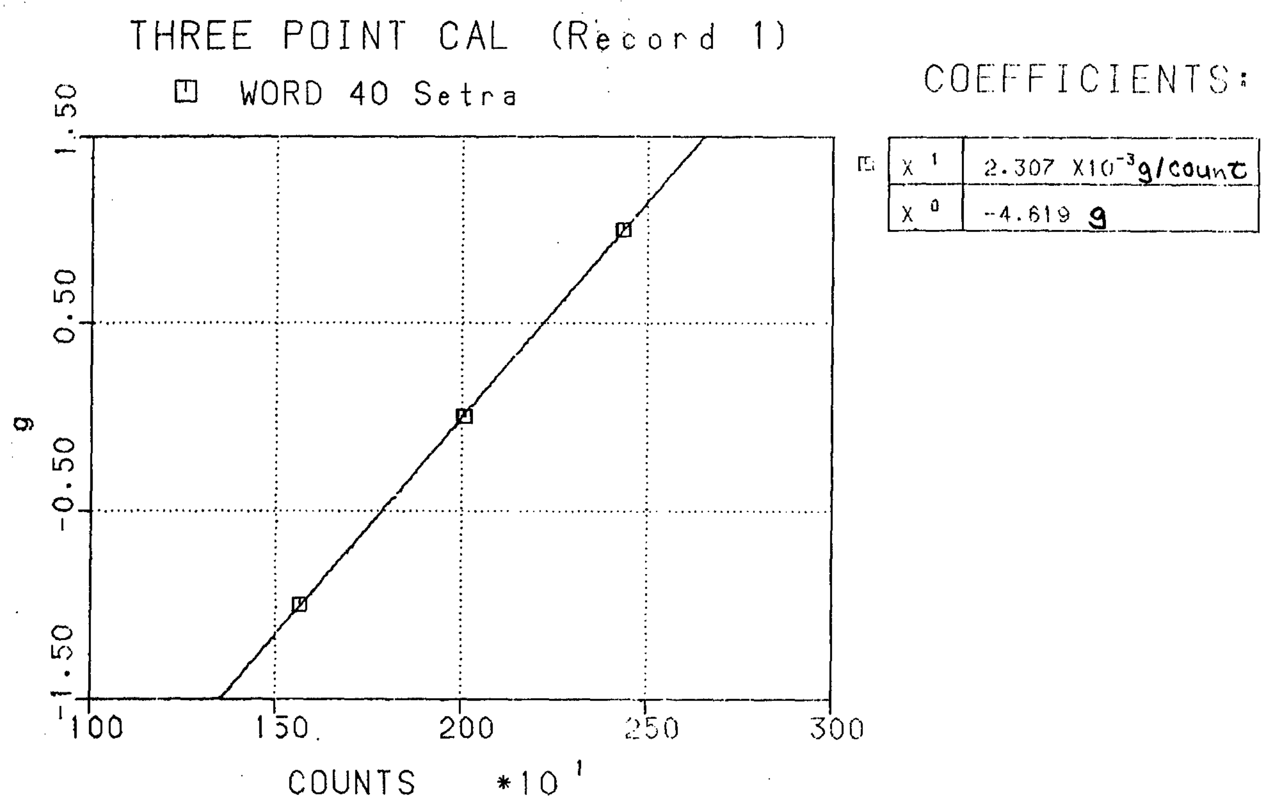
Figure 80. Block Diagram for F-16 Wing Test and Calibration





Note: For each g level, mean value of DC Cals expanded were used for curvefit.

Figure 81. Three point cal time history for multi-channel calibration



PLSQ POLYNOMIAL LEAST SQUARE CURVE FIT ERROR ANALYSIS

I	X= Counts	Y= g in	Y= FITTED	ERROR(E)	C(I)
1	0.24324E+04	0.10000E+01	0.99250E+00	-0.74997E-02	0.23071344E-02
2	0.20060E+04	0.00000E+00	0.87385E-02	0.87385E-02	-0.46193733E+01
3	0.15637E+04	-0.10000E+01	-0.10117E+01	-0.11707E-01	
4	0.20088E+04	0.00000E+00	0.15199E-01	0.15199E-01	
5	0.24336E+04	0.10000E+01	0.99527E+00	-0.47307E-02	

EMAX: 0.15199E-01 ERMS: 0.102279E-01 EMEQ: 0.000000E+00

Figure X. Curvefit Data from Record 1 Three Point Calibration

Figure 82. Three point Calibration Best Fit Straight Line

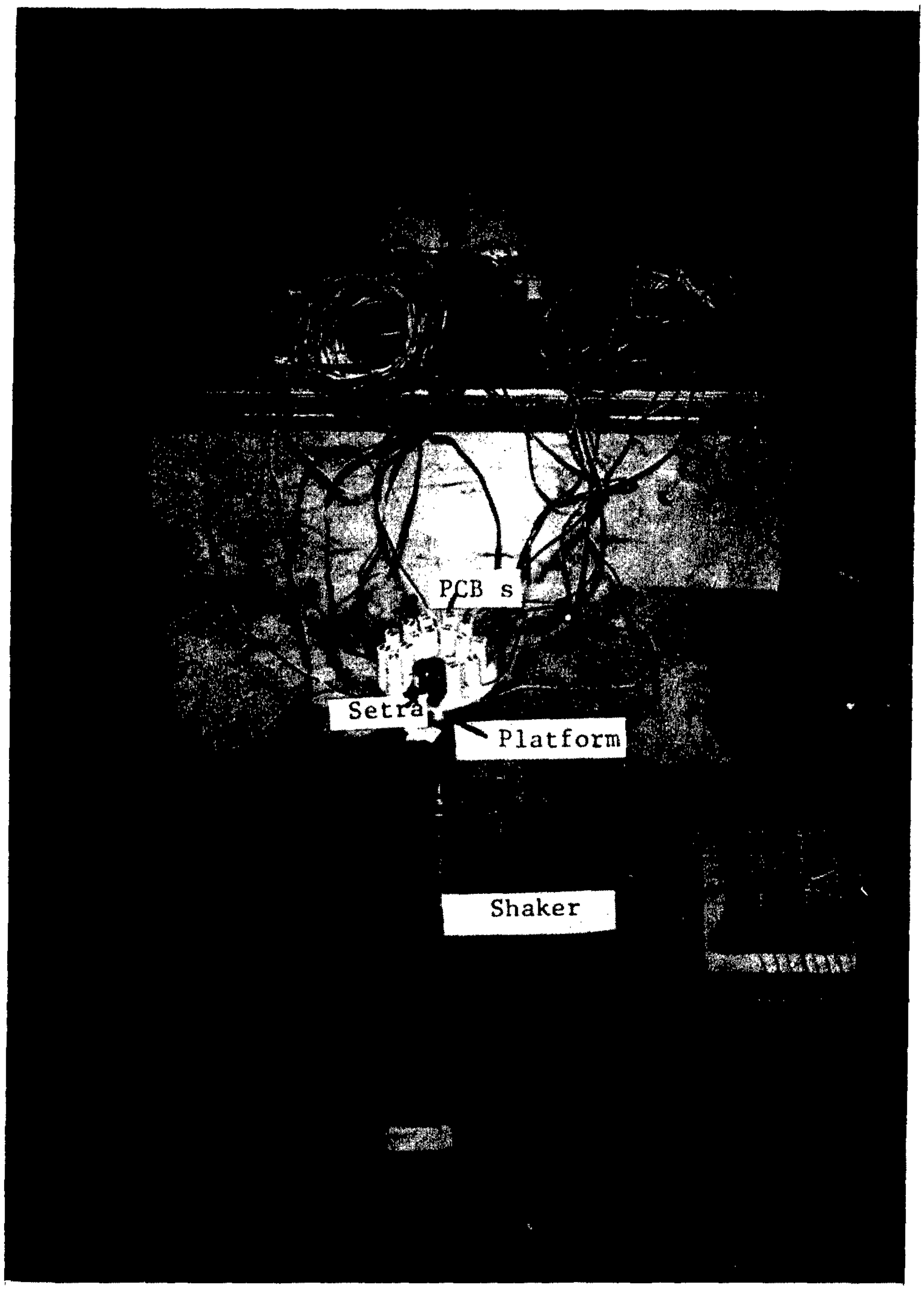


Figure 83. Photo of multiple accelerometer calibration setup

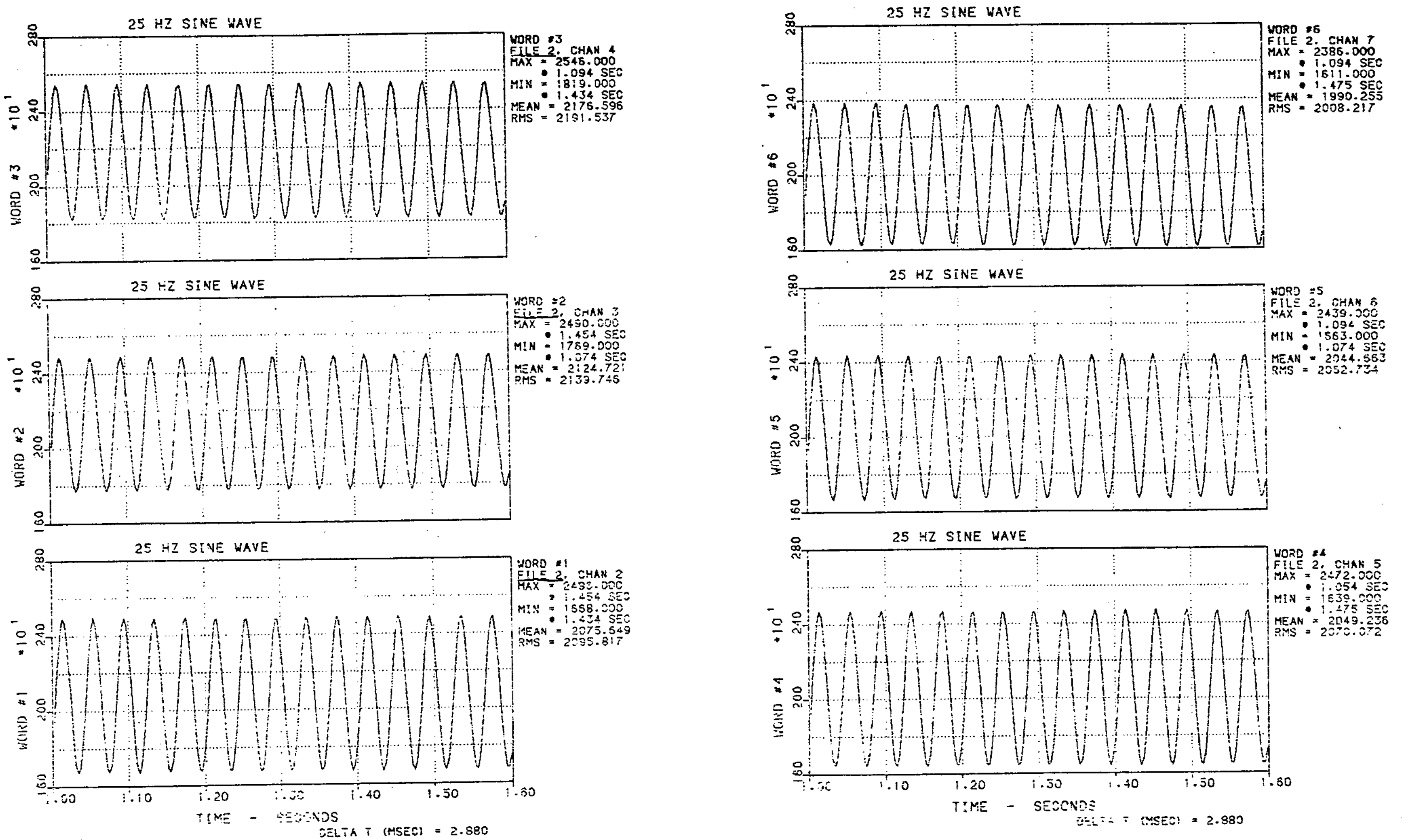


Figure 84. Sine Wave Calibrations for PCB words 1-6

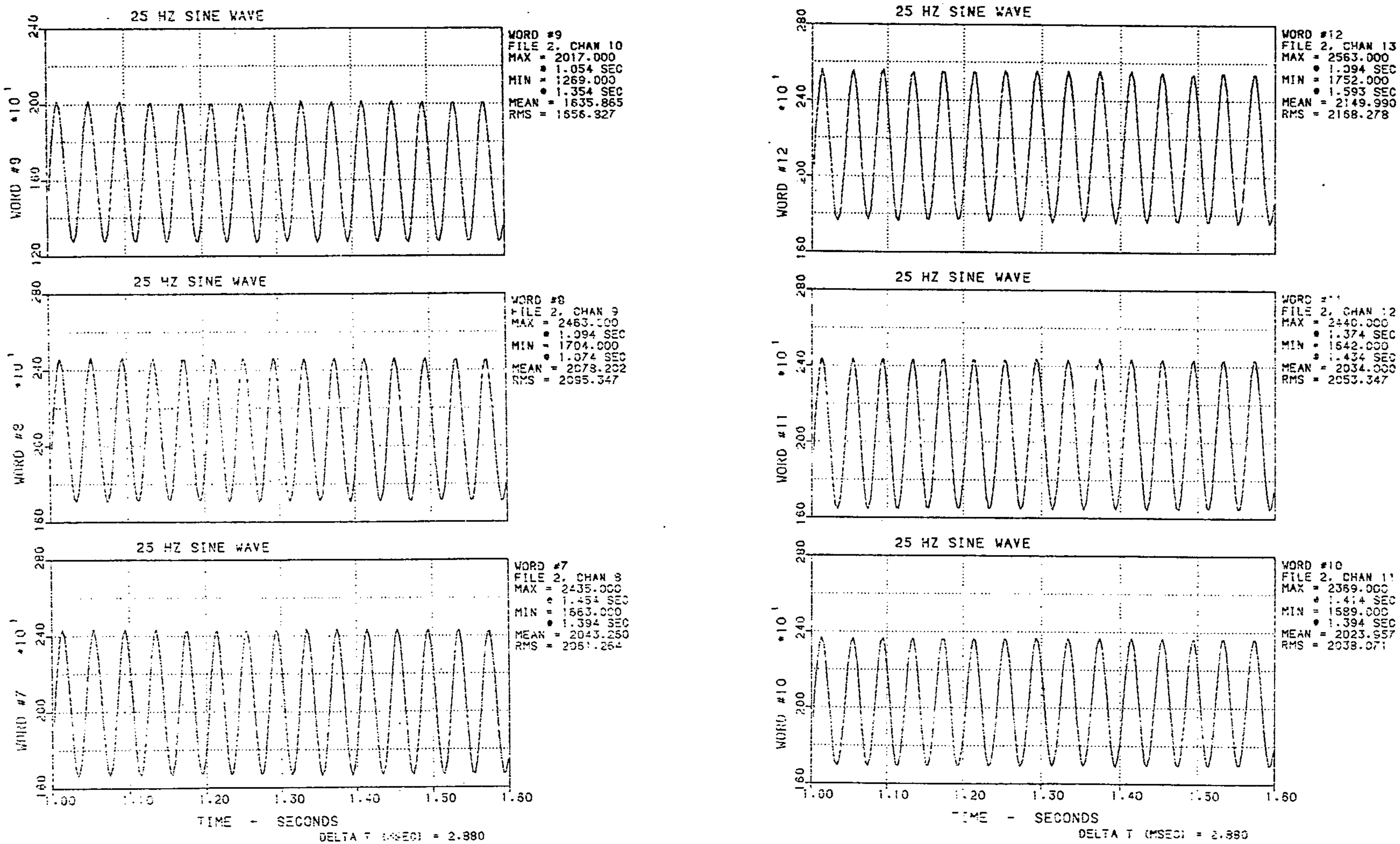


Figure 85. Sine Wave Calibrations for PCB words 7-12

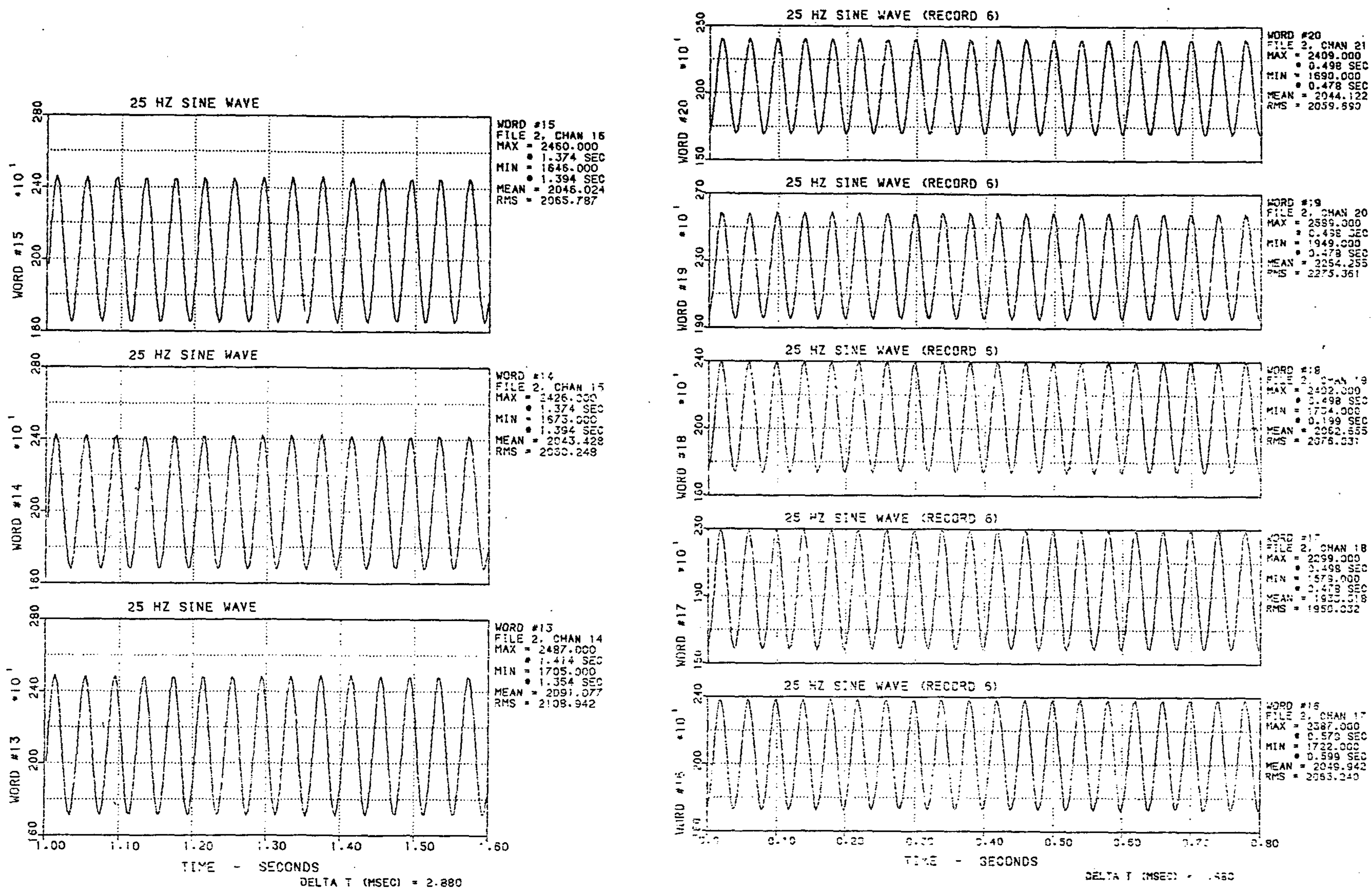


Figure 86. Sine Wave Calibrations for PCB words 13-20

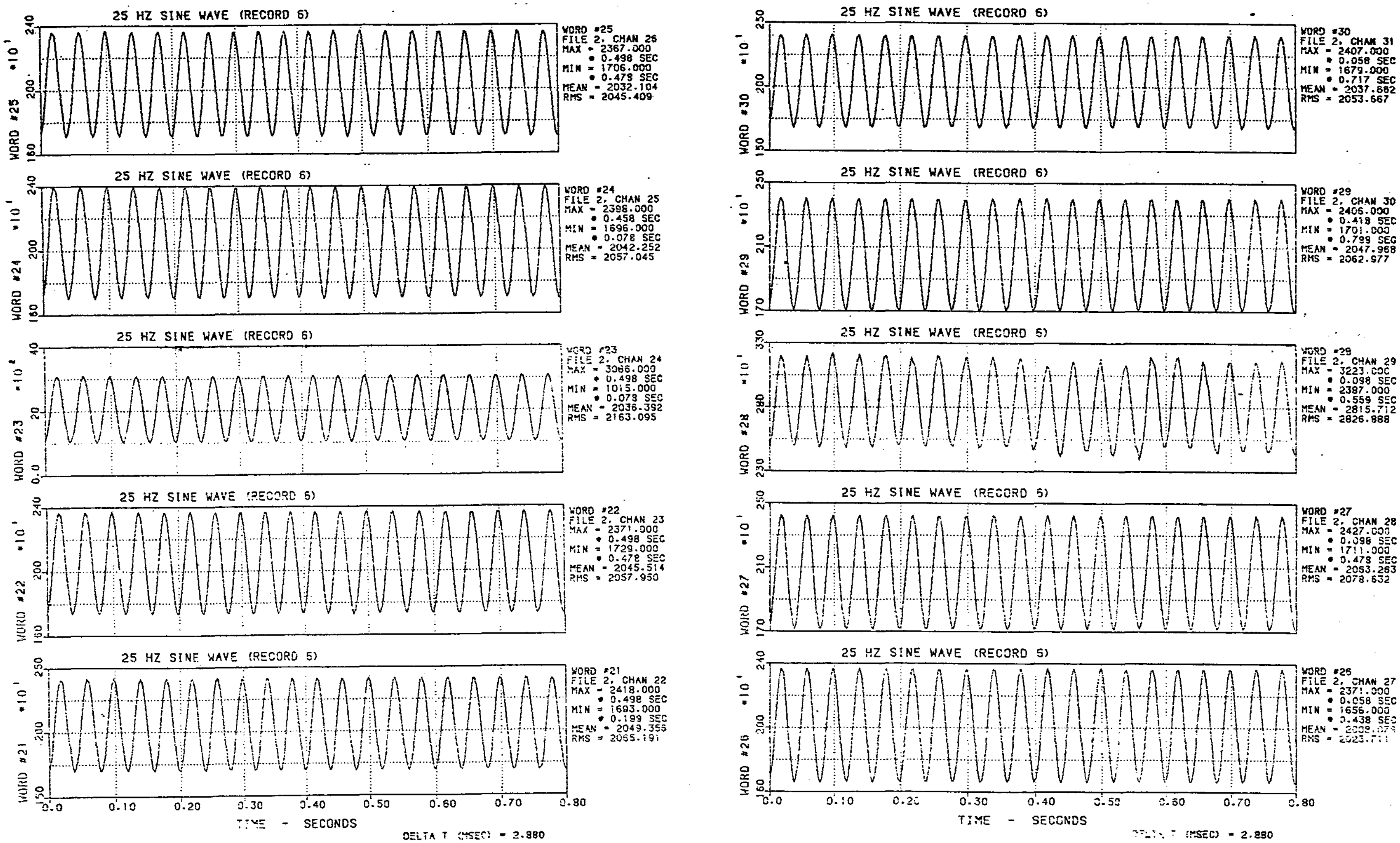


Figure 87. Sine Wave Calibrations for PCB words 21-30

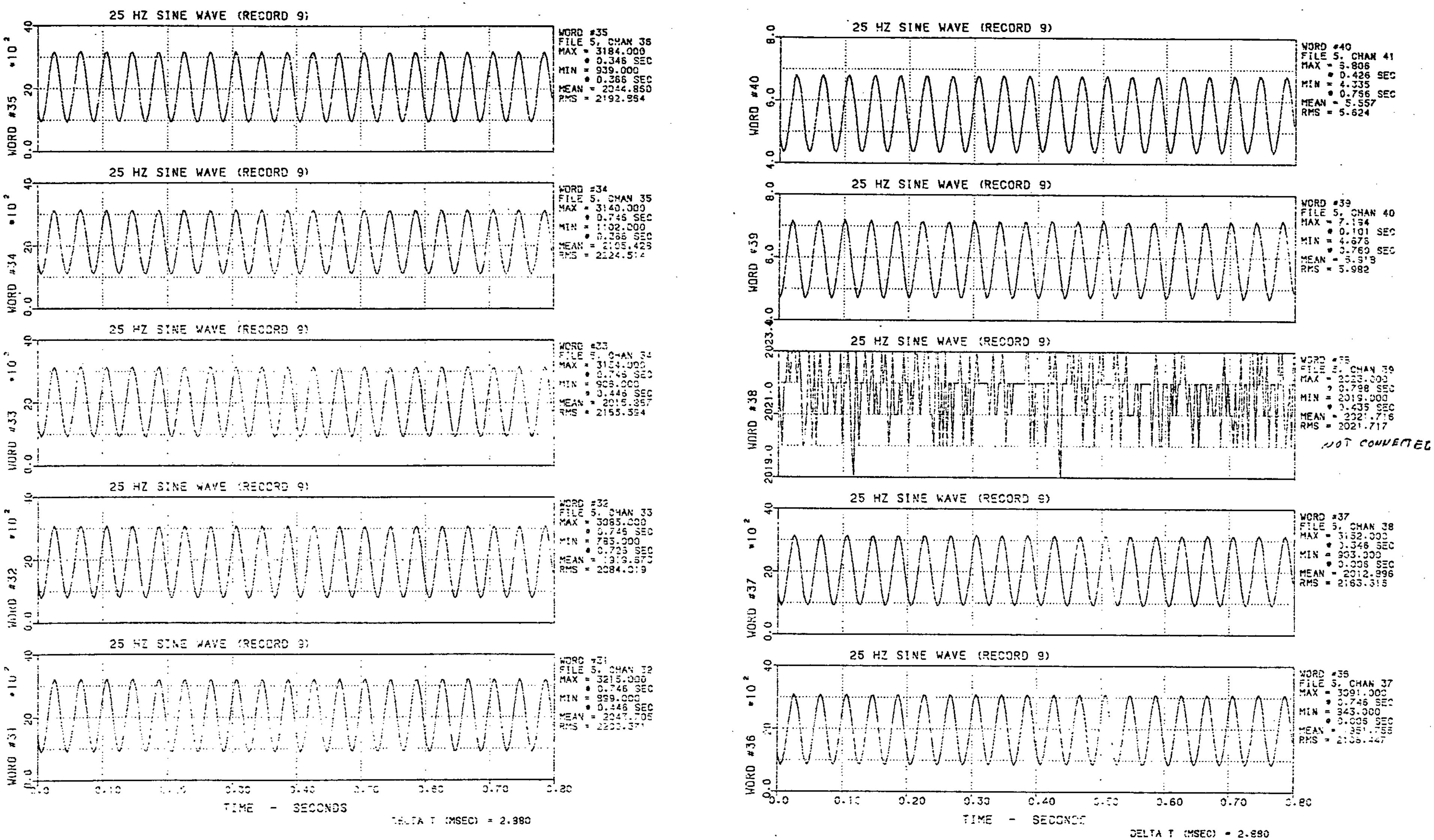


Figure 88. Sine Wave Calibrations for PCB words 31-40

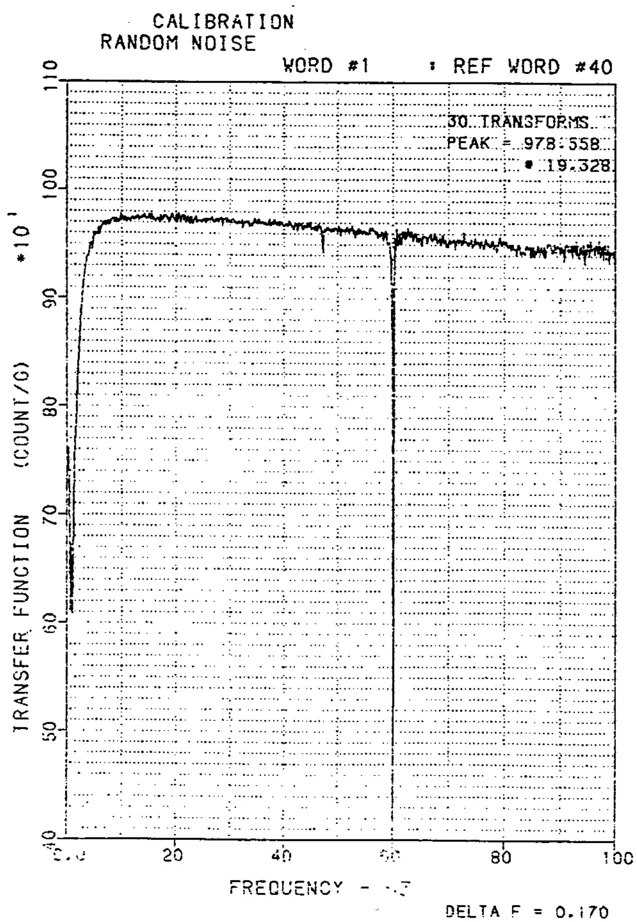


Figure 89. Transfer Function for word 1 (PCB SN 841)

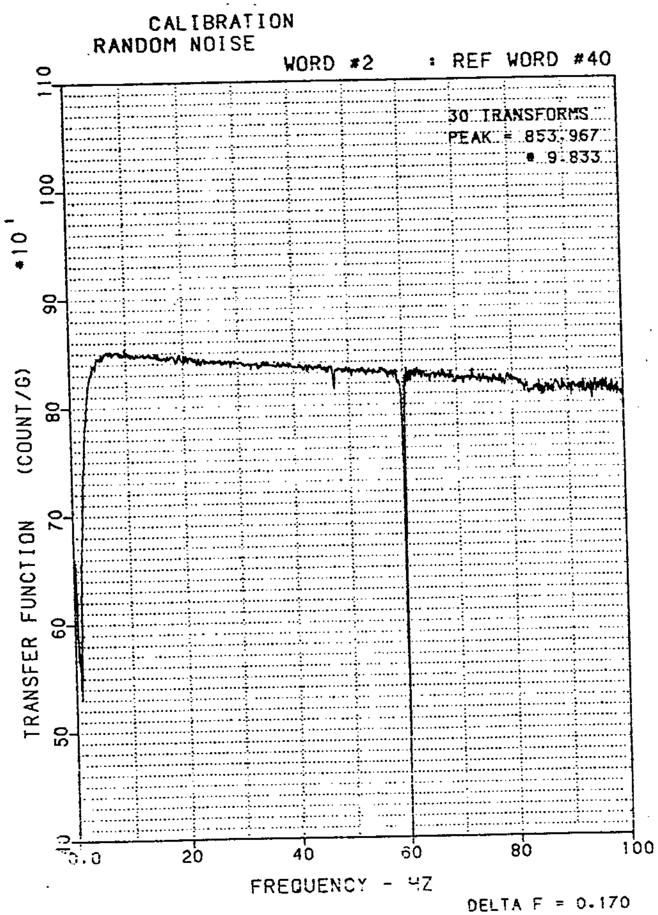


Figure 90. Transfer Function for word 2 (PCB SN 970)

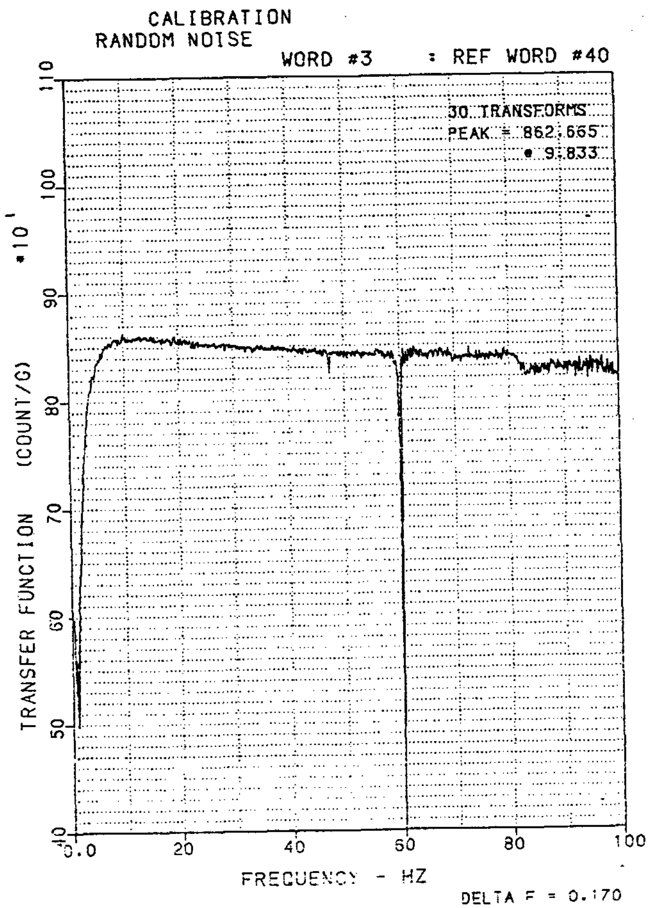


Figure 91. Transfer Function for word 3 (PCB SN 1089)

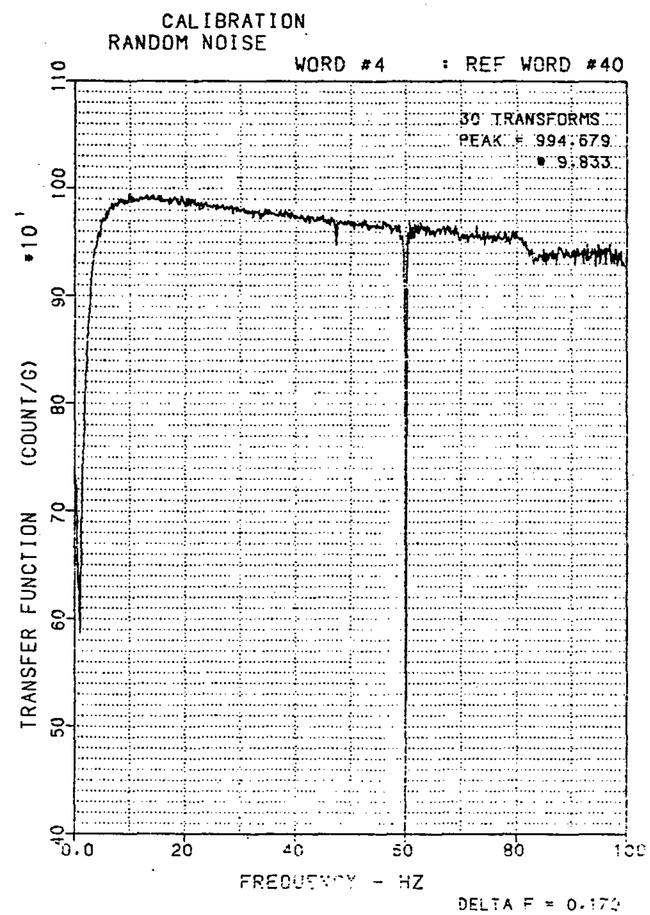


Figure 92. Transfer Function for word 4 (PCB SN 936)

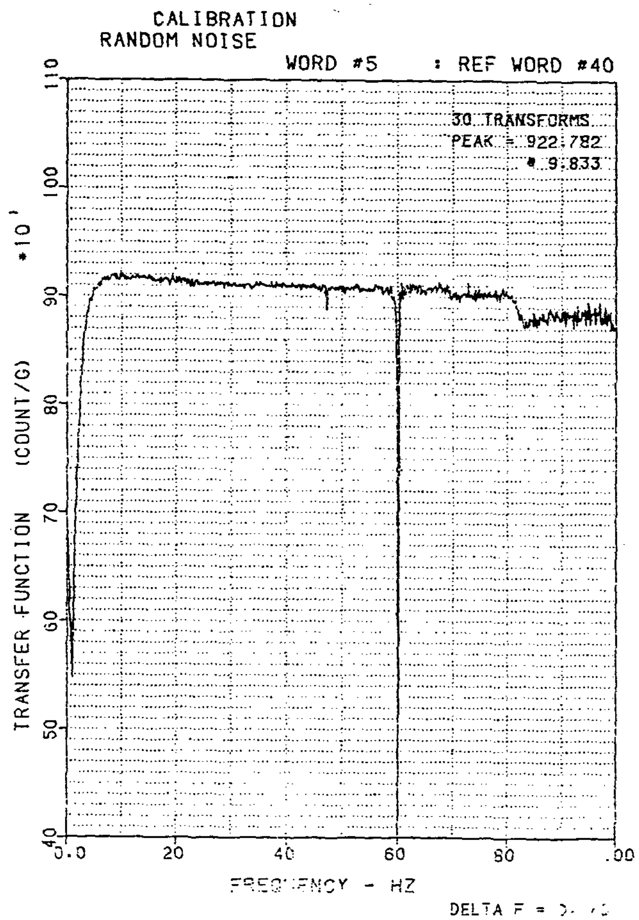


Figure 93. Transfer Function for word 5 (PCB SN 857)

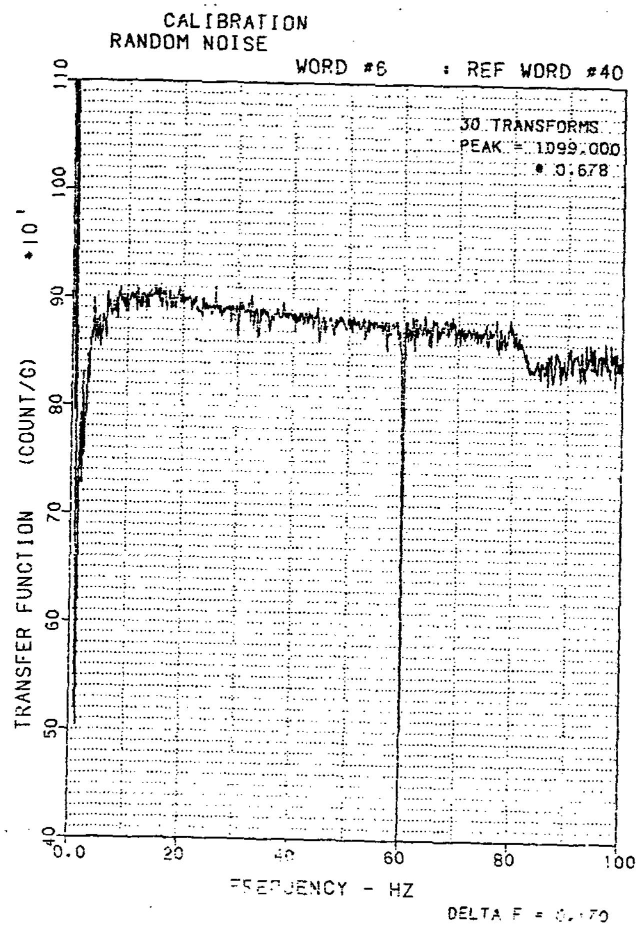


Figure 94. Transfer Function for word 6 (PCB SN 1016)

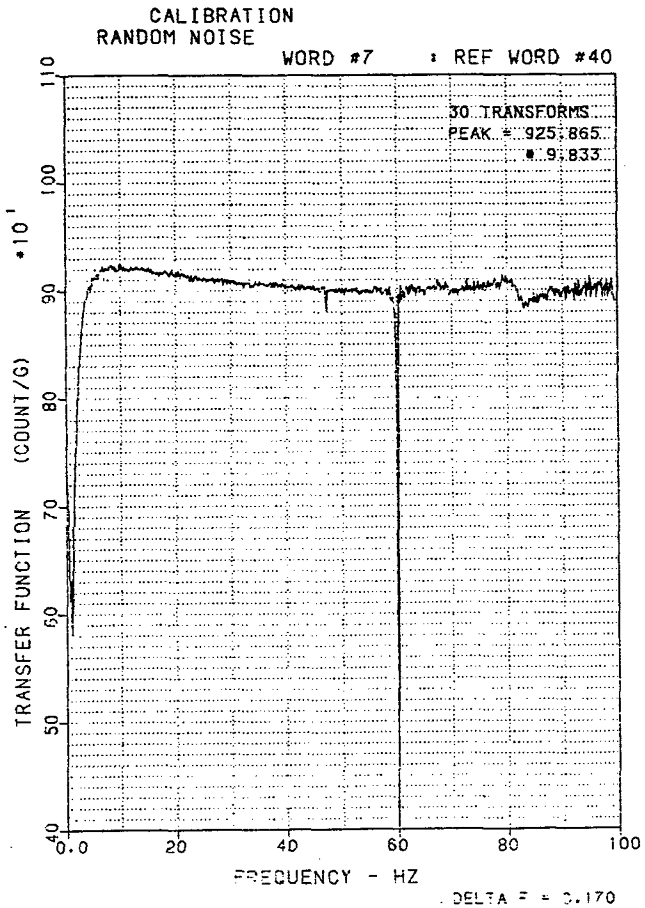


Figure 95. Transfer Function for word 7 (PCB SN 1101)

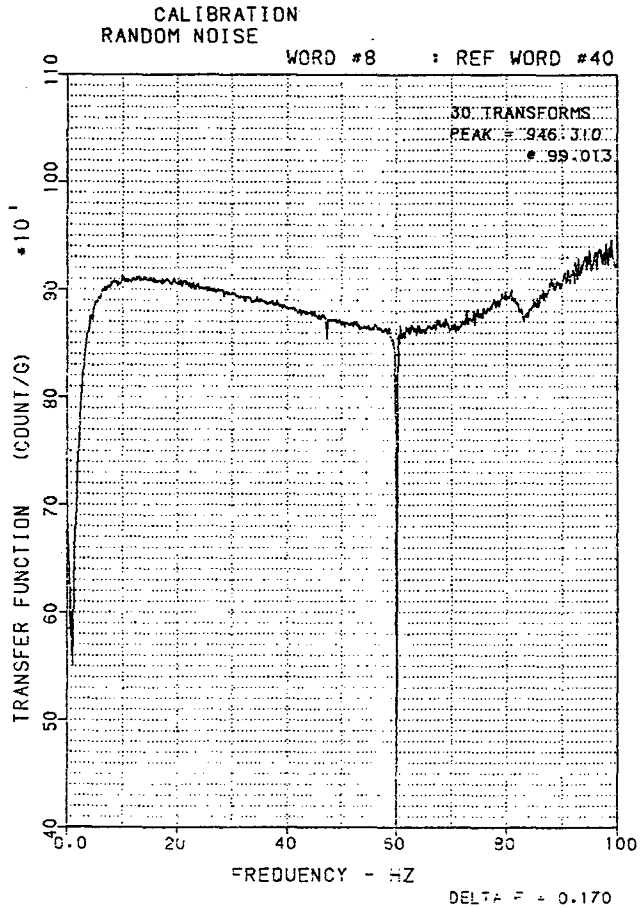


Figure 96. Transfer Function for word 8 (PCB SN 1134)

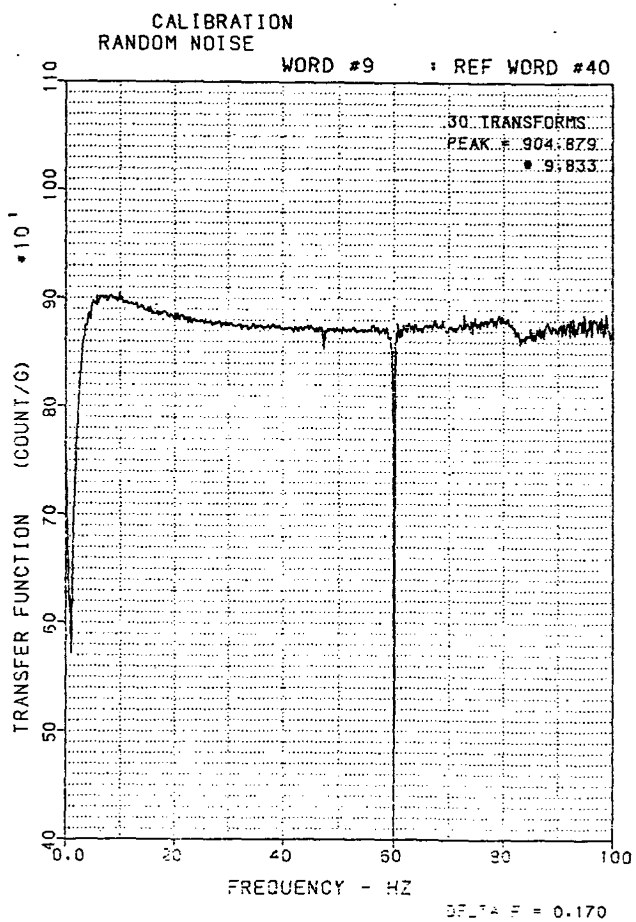


Figure 97. Transfer Function for word 9 (PCB SN 1091)

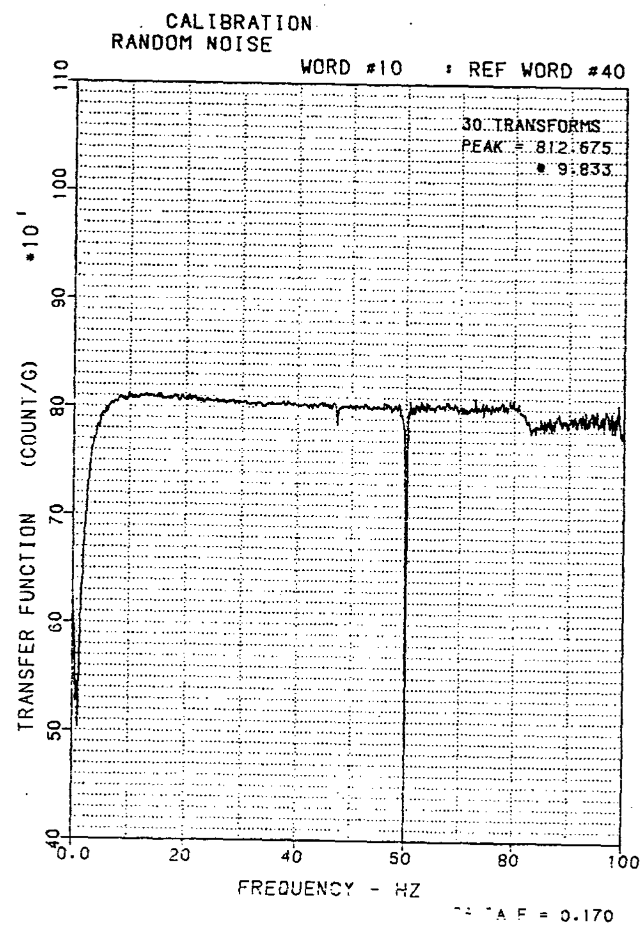


Figure 98. Transfer Function for word 10 (PCB SN 1076)

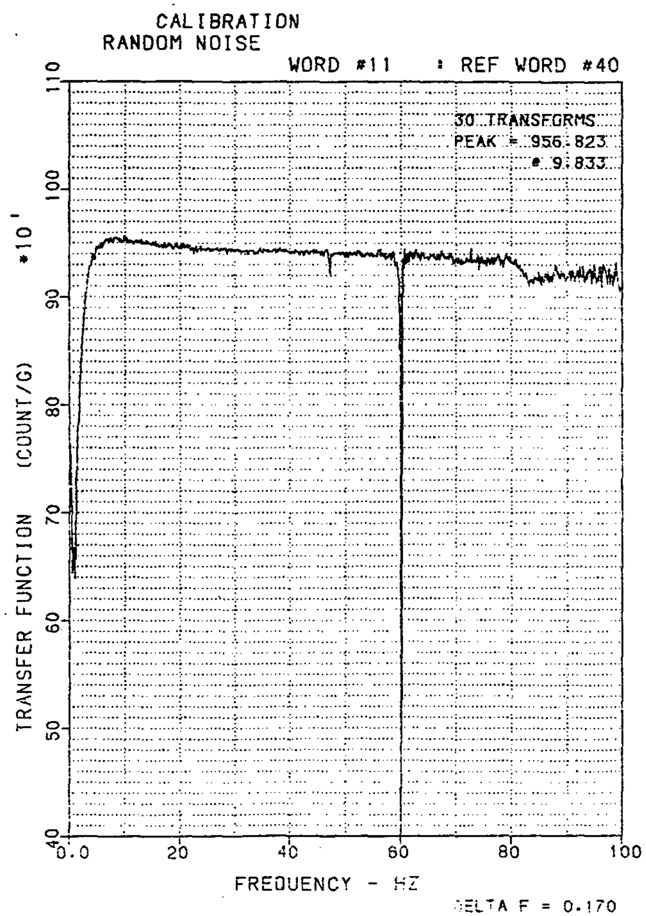


Figure 99. Transfer Function for word 11 (PCB SN 1063)

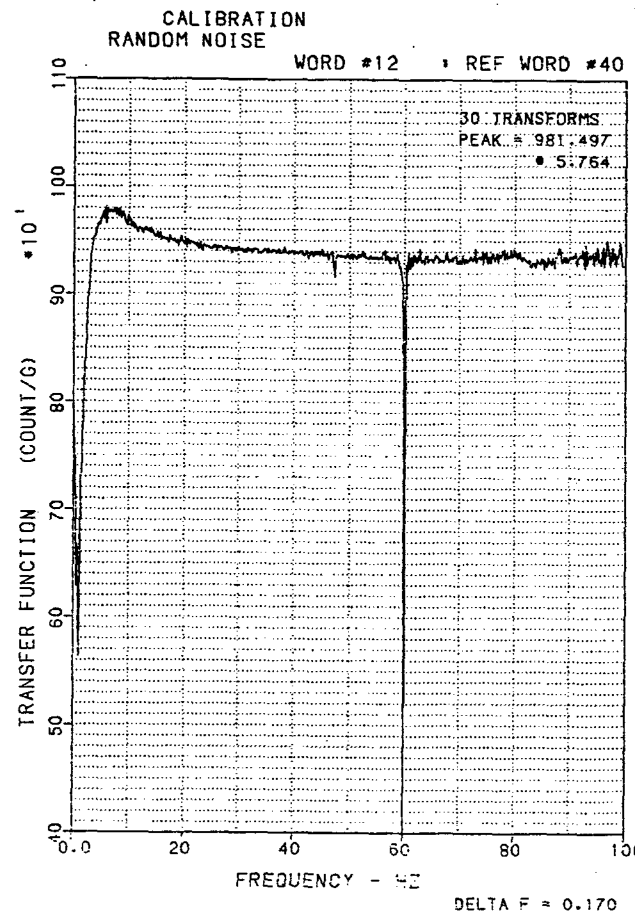


Figure 100. Transfer Function for word 12 (PCB SN 907)

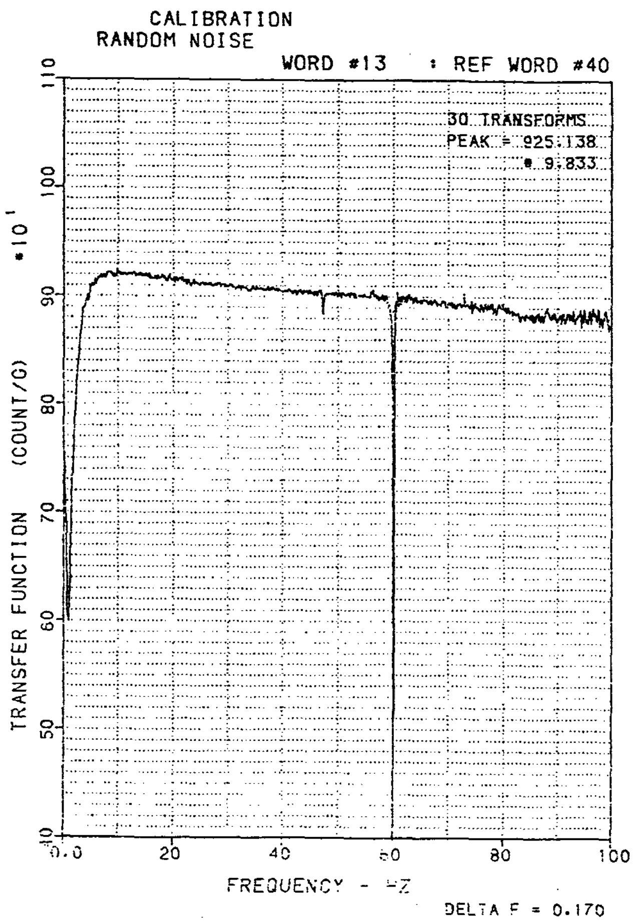


Figure 101. Transfer Function for word 13 (PCB SN 889)

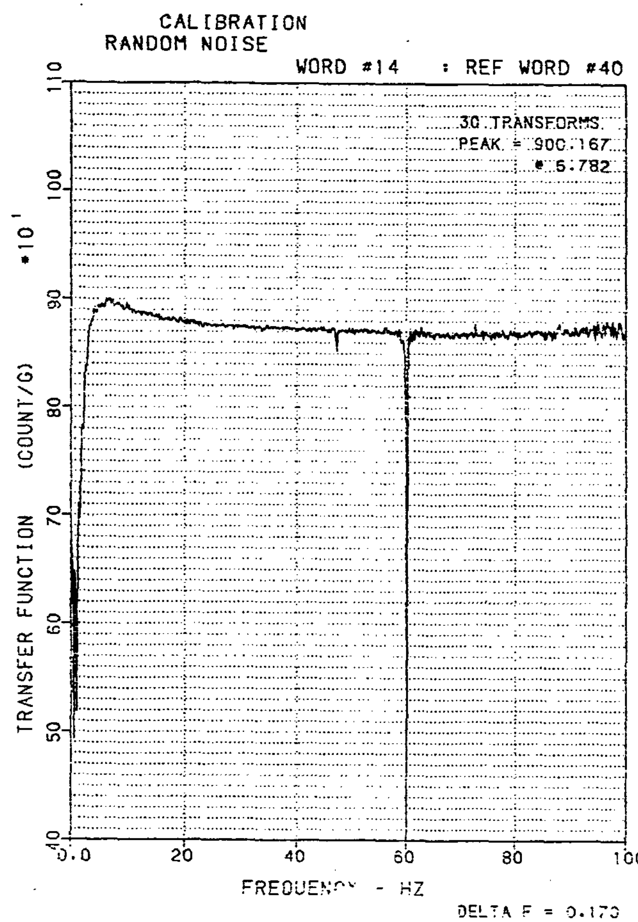


Figure 102. Transfer Function for word 14 (PCB SN 892)

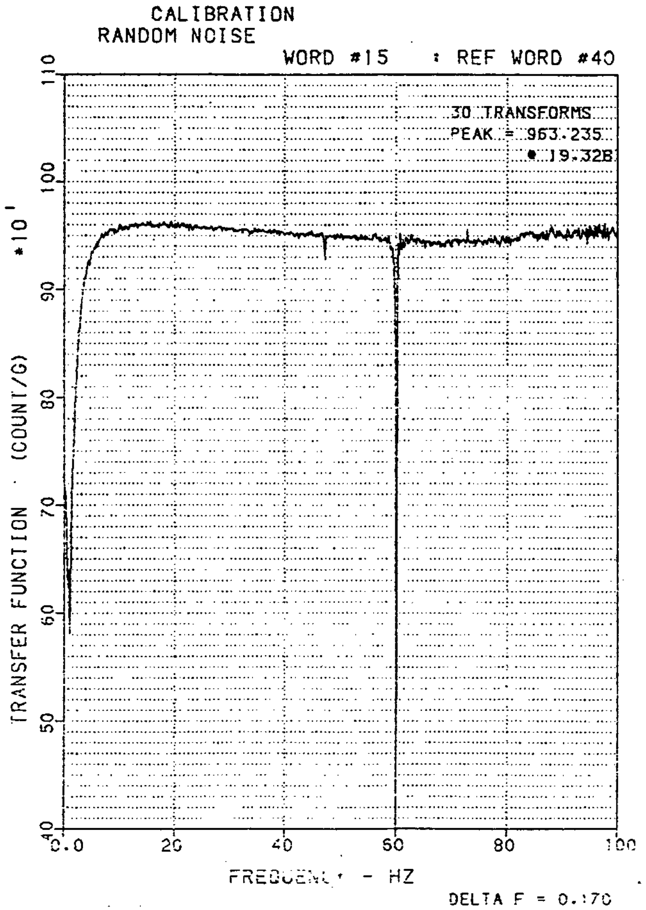


Figure 103. Transfer Function for word 15 (PCB SN 546)

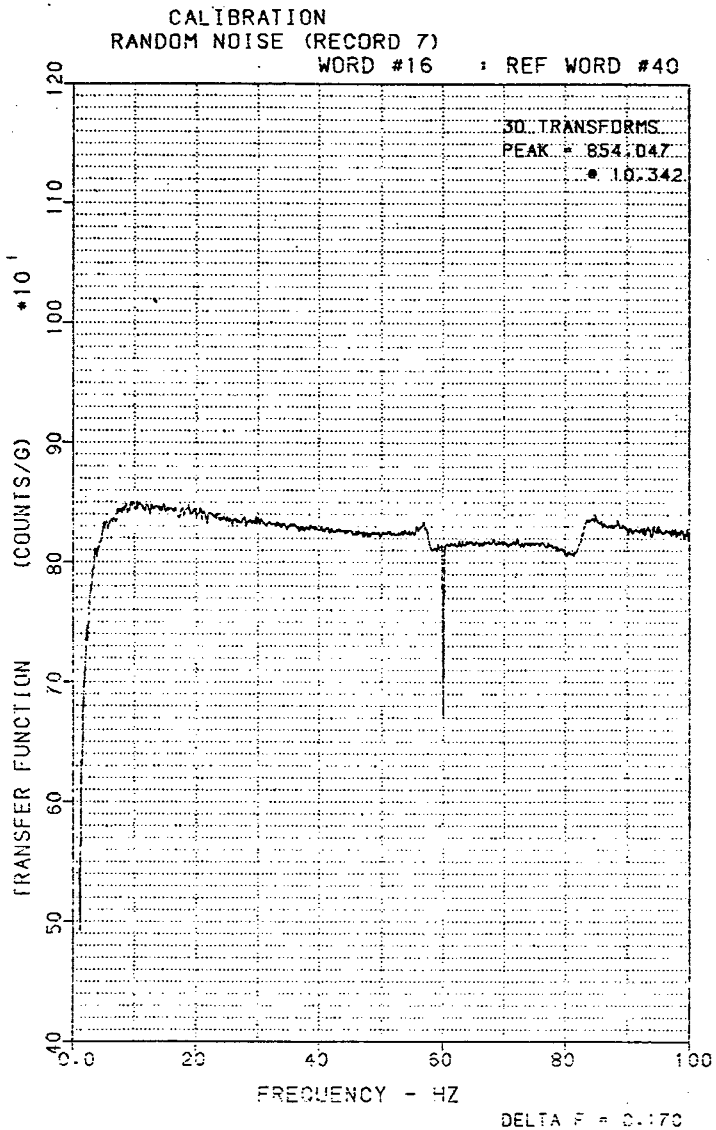


Figure 104. Transfer Function for word 16 (PCB SN 1174)

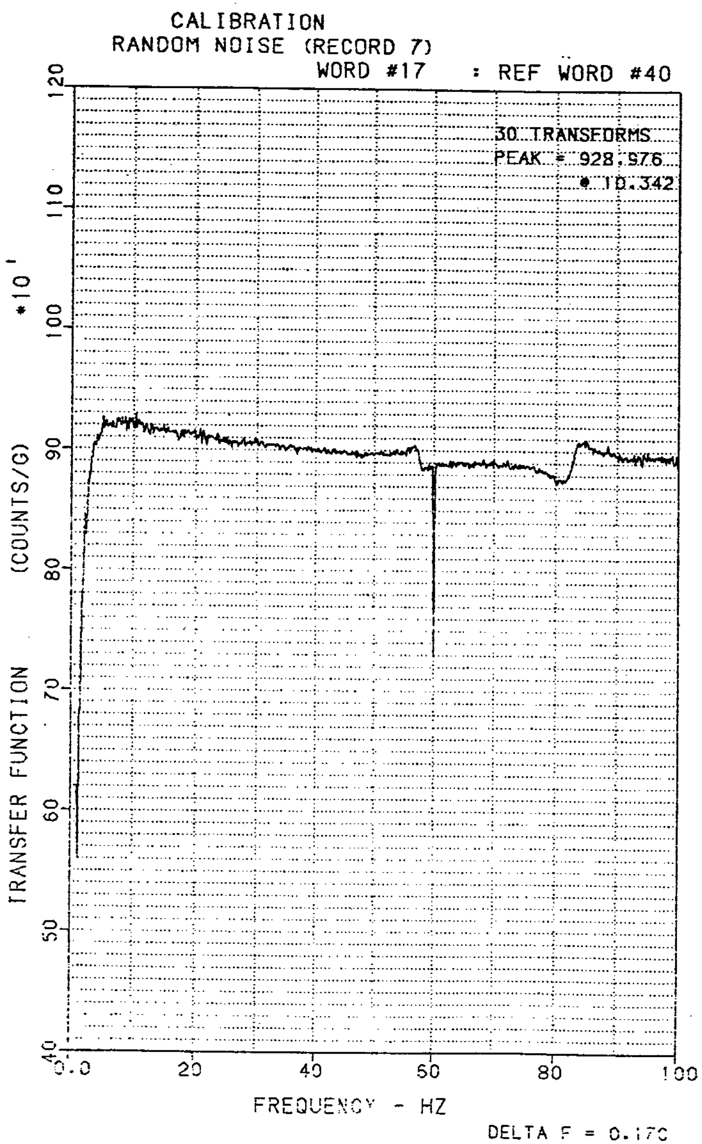


Figure 105. Transfer Function for word 17 (PCB SN 1170)

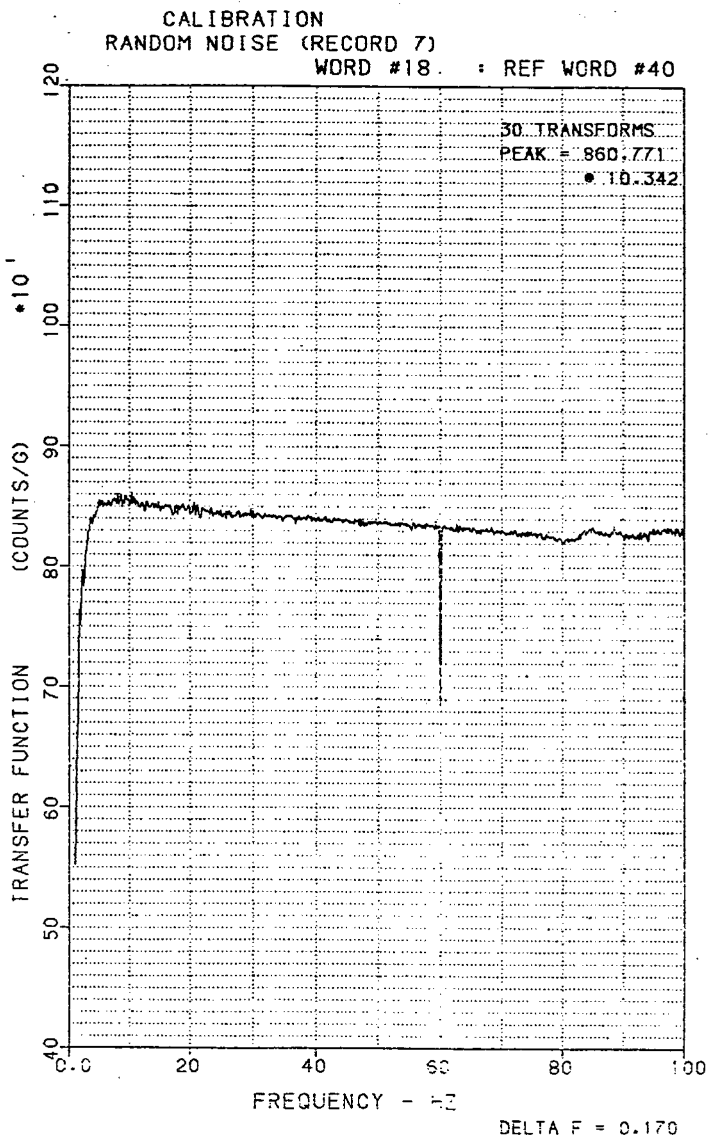


Figure 106. Transfer Function for word 18 (PCB SN 1193)

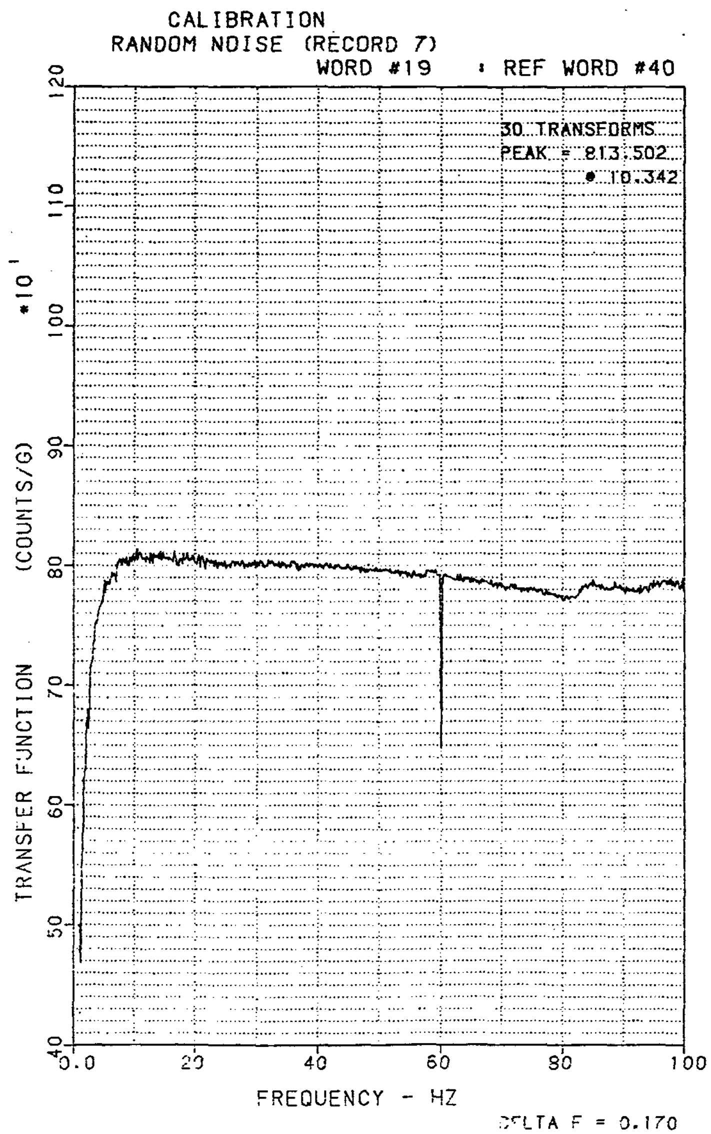


Figure 107. Transfer Function for word 19 (PCB SN 1258)

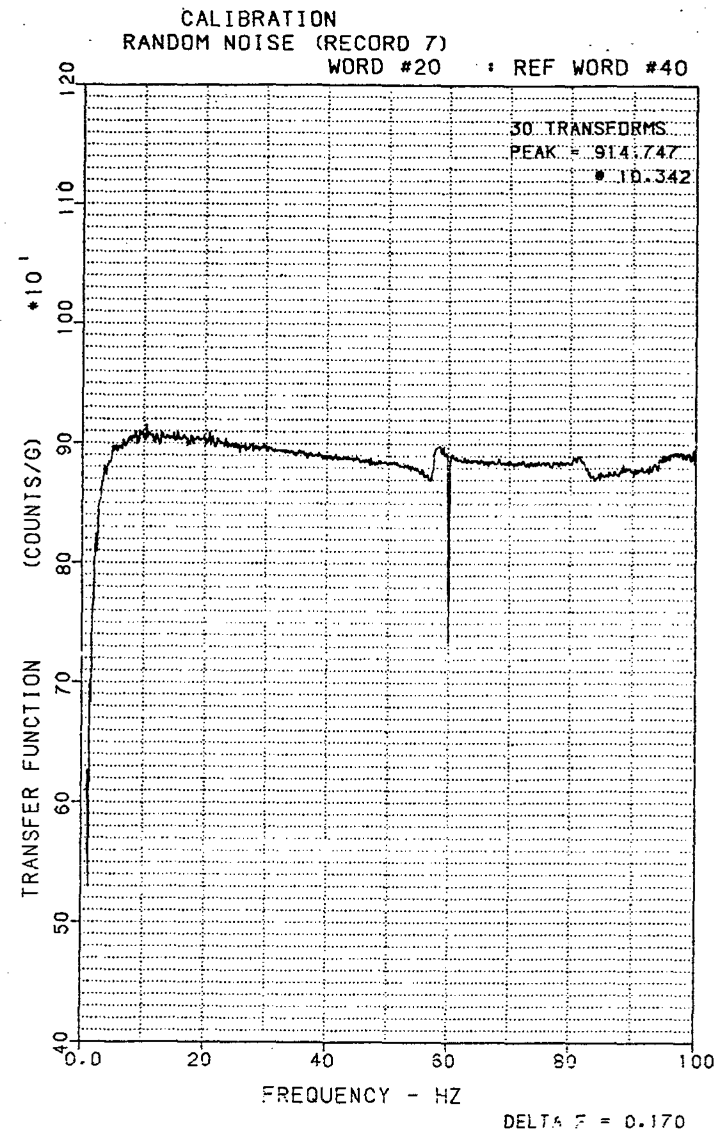


Figure 108. Transfer Function for word 20 (PCB SN 1210)

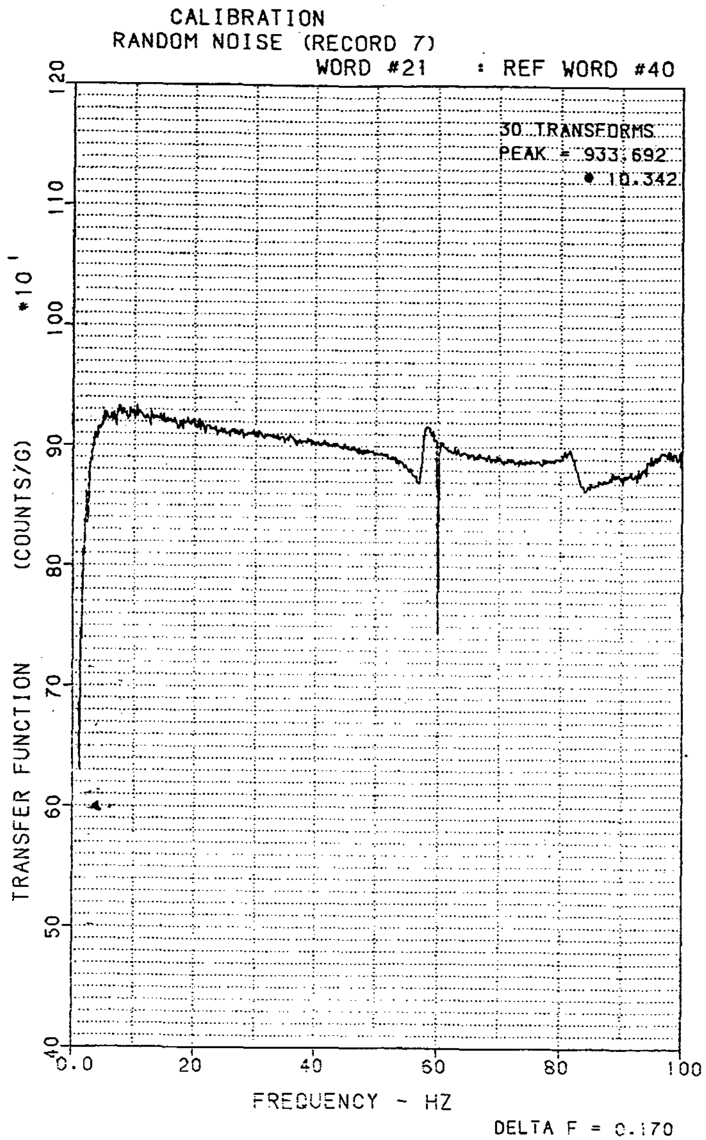


Figure 109. Transfer Function for word 21 (PCB SN 1237)

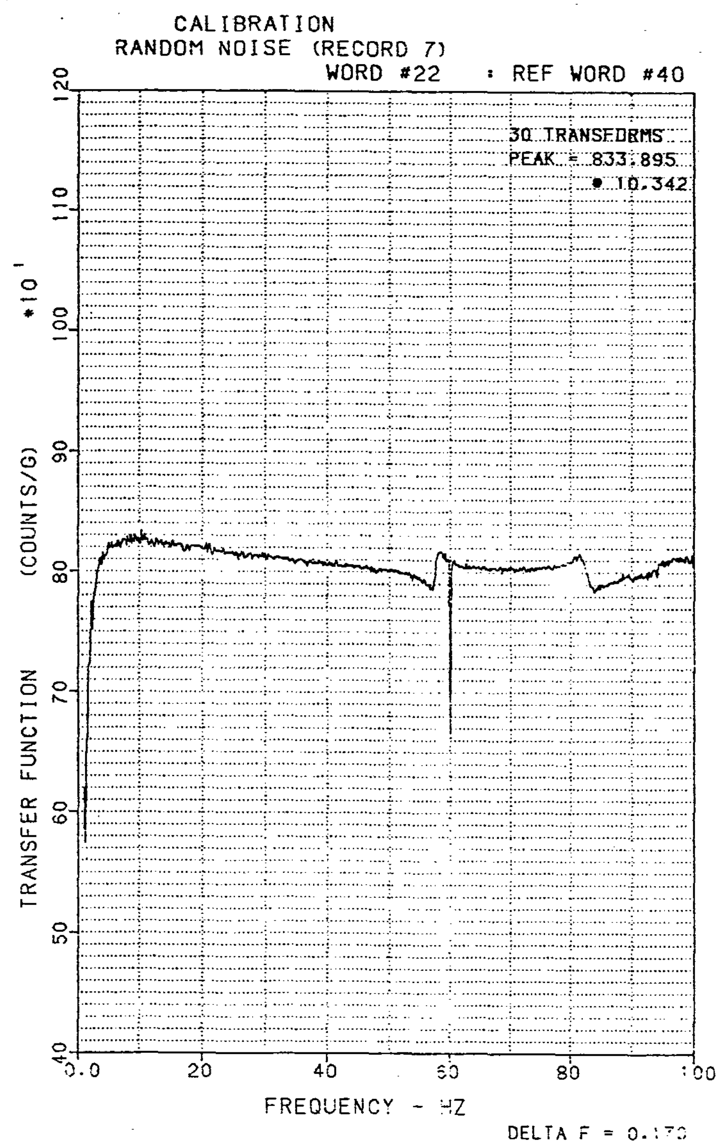


Figure 110. Transfer Function for word 22 (PCB SN 1243)

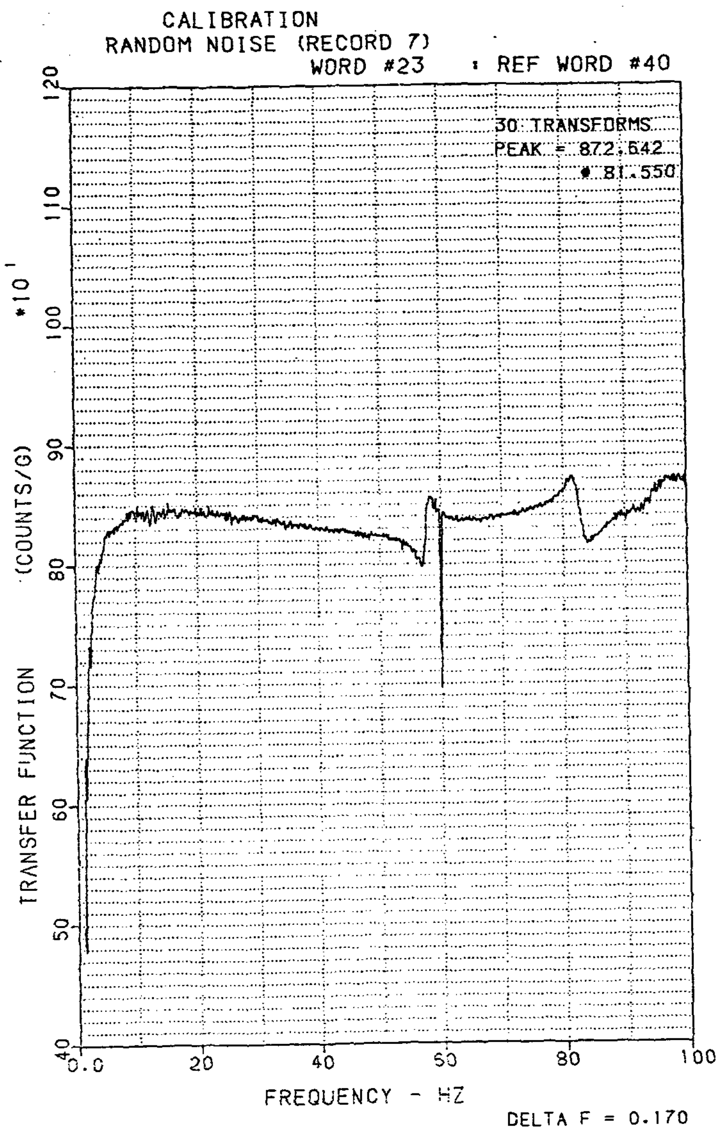


Figure 111. Transfer Function for word 23 (PCB SN 1153)

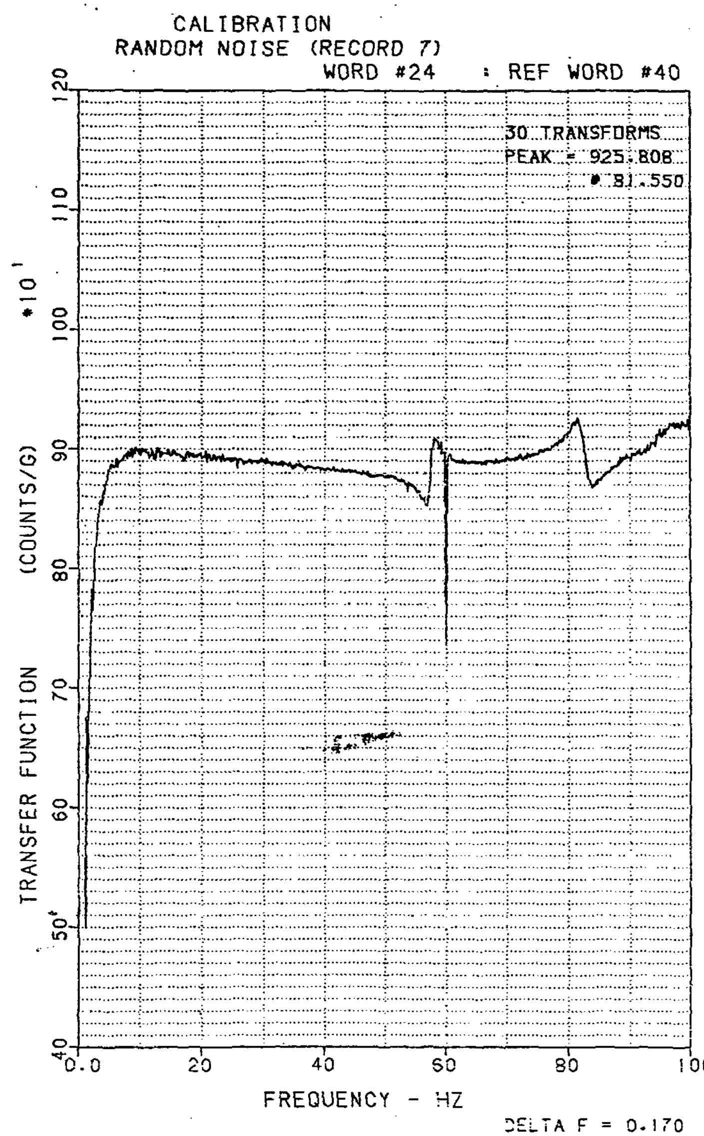


Figure 112. Transfer Function for word 24 (PCB SN 1139)

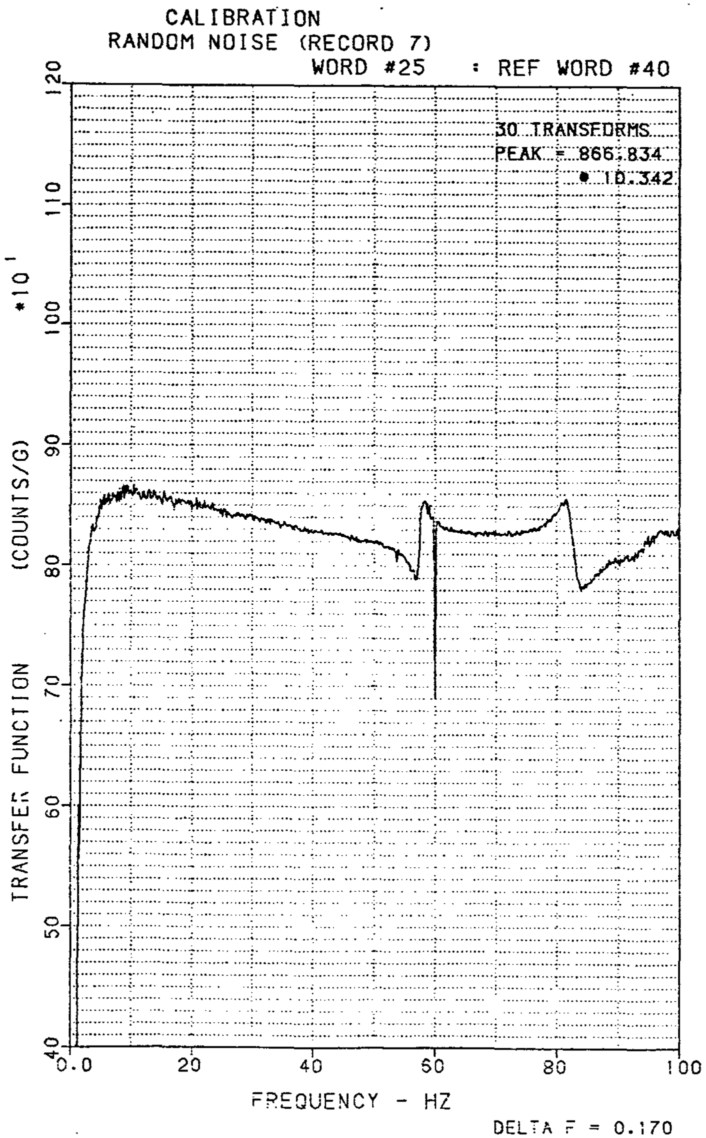


Figure 113. Transfer Function for word 25 (PCB SN 1219)

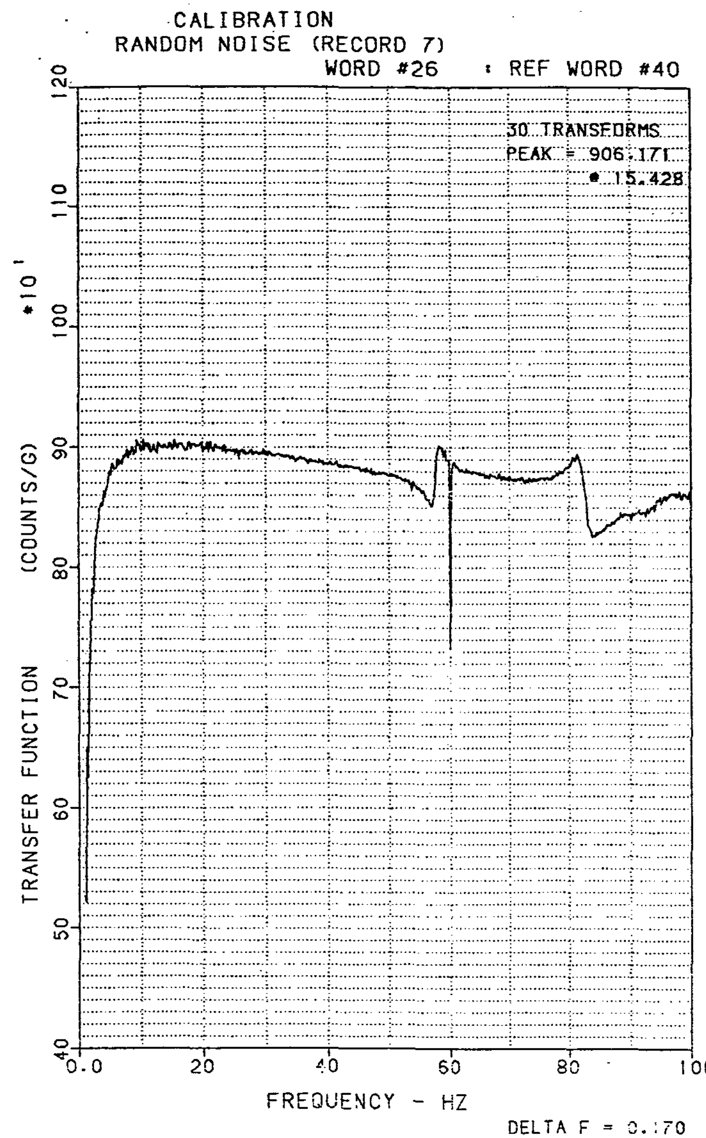


Figure 114. Transfer Function for word 26 (PCB SN 1213)

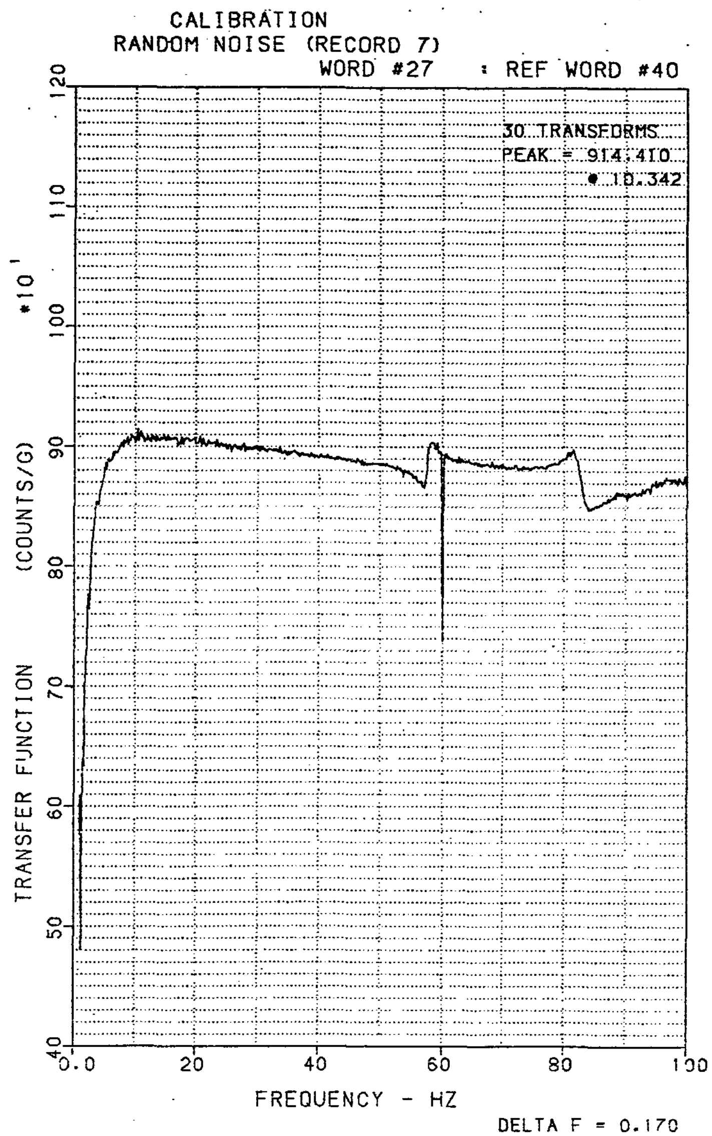


Figure 115. Transfer Function for word 27 (PCB SN 1247)

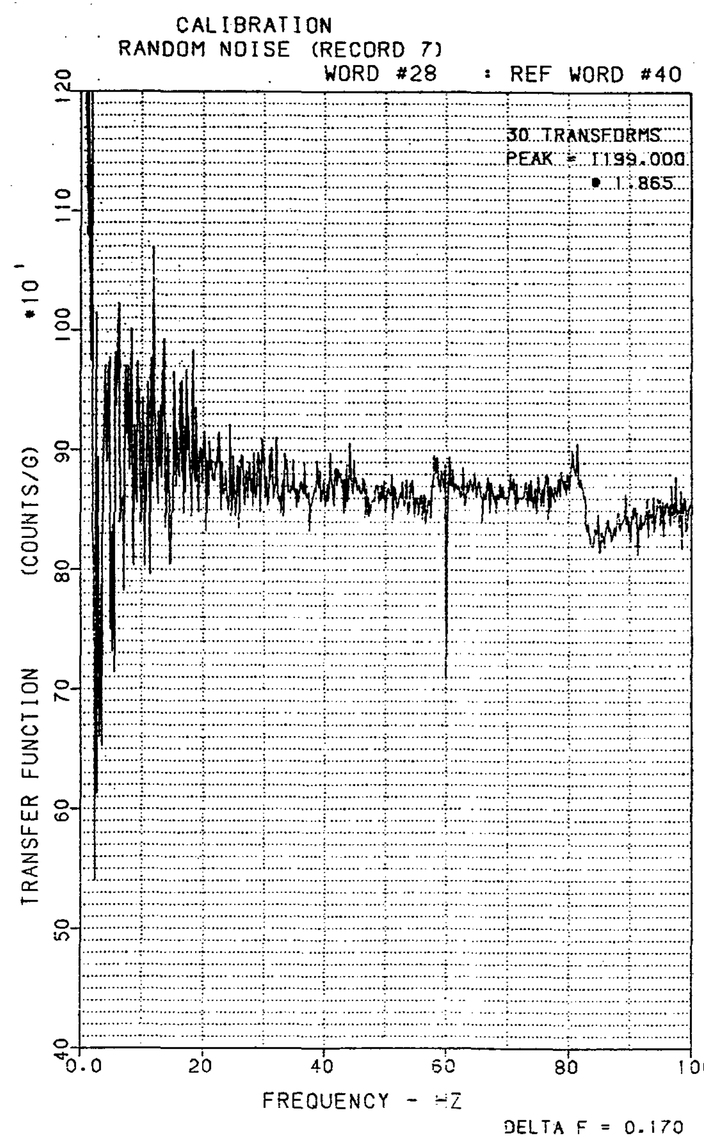


Figure 116. Transfer Function for word 28 (PCB SN 1255)

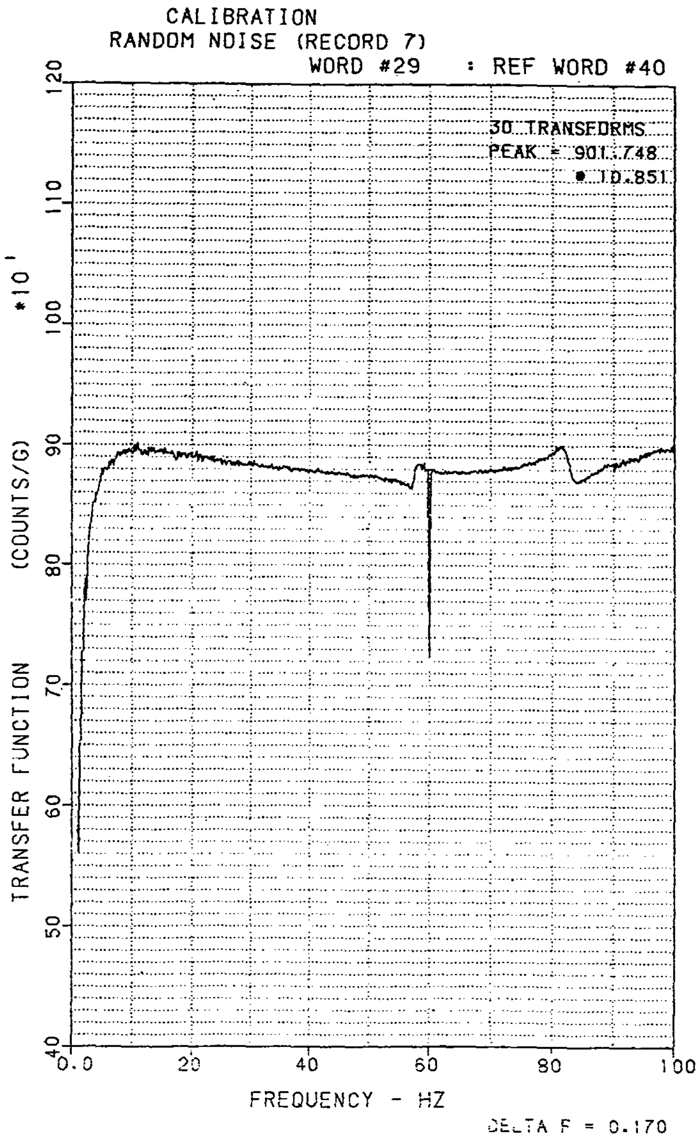


Figure 117. Transfer Function for word 29 (PCB SN 1242)

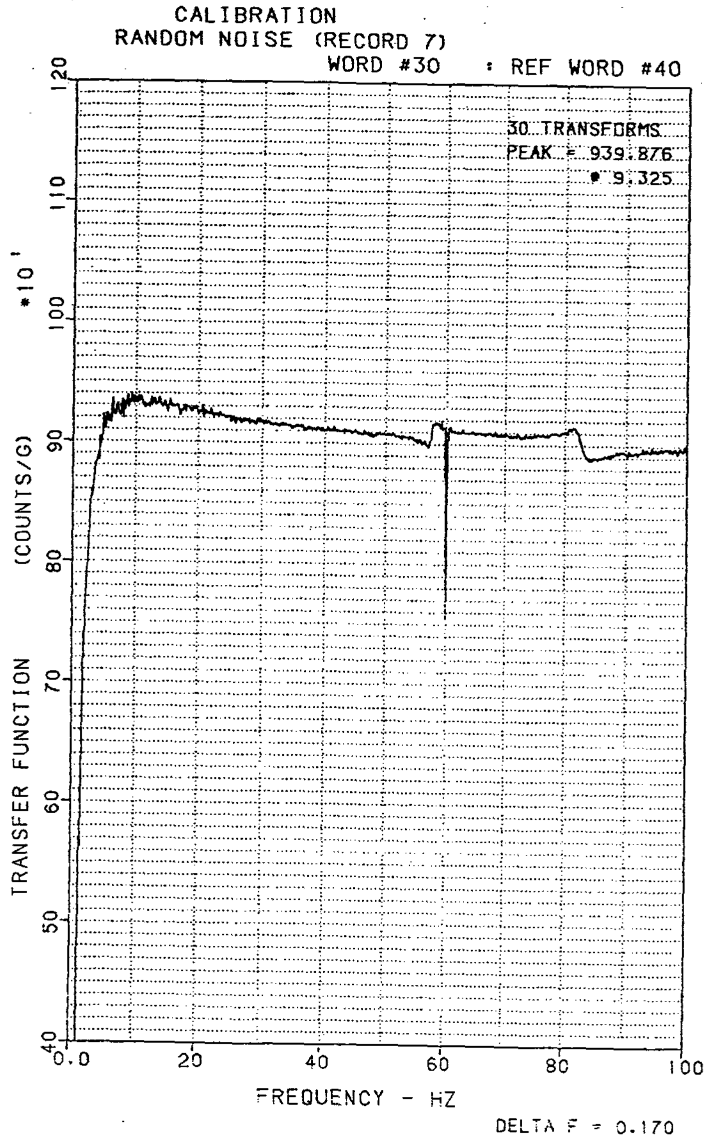


Figure 118. Transfer Function for word 30 (PCB SN 1249)

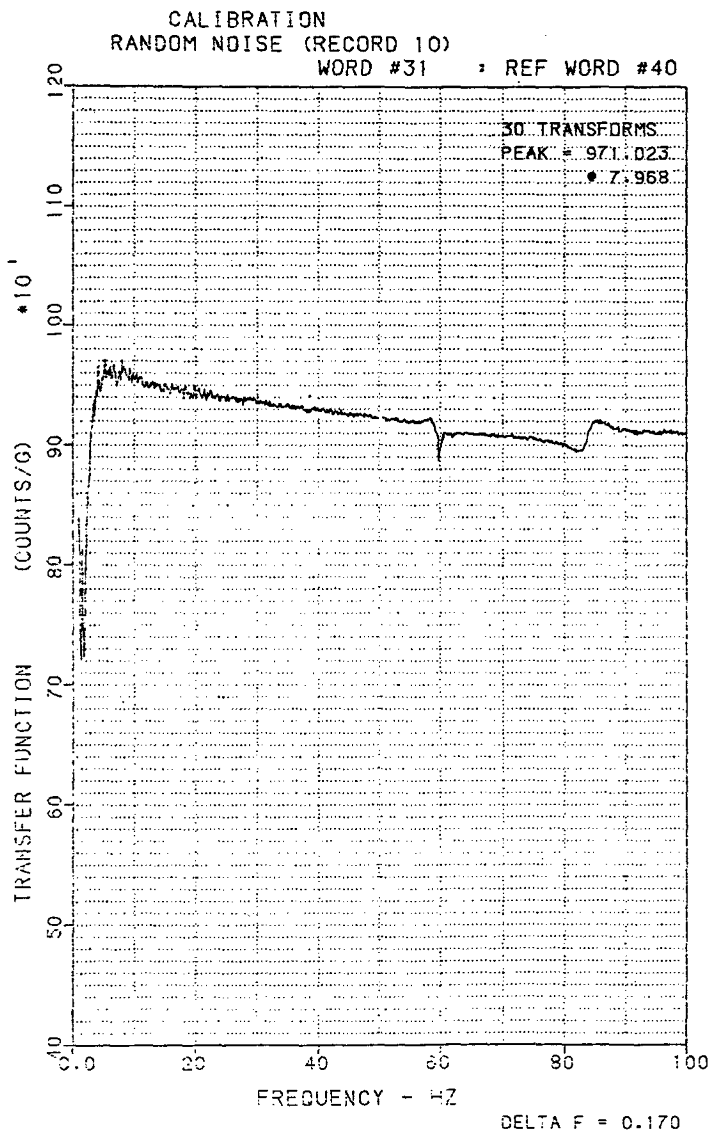


Figure 119. Transfer Function for word 31 (PCB SN 1212)

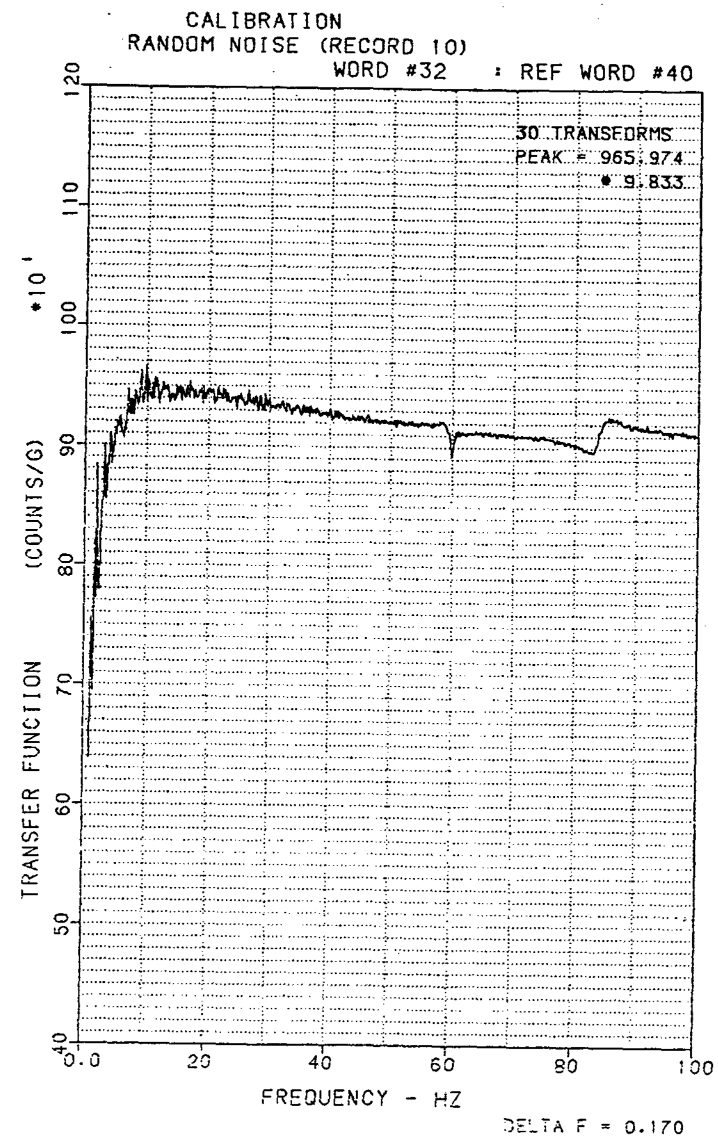


Figure 120. Transfer Function for word 32 (PCB SN 867)

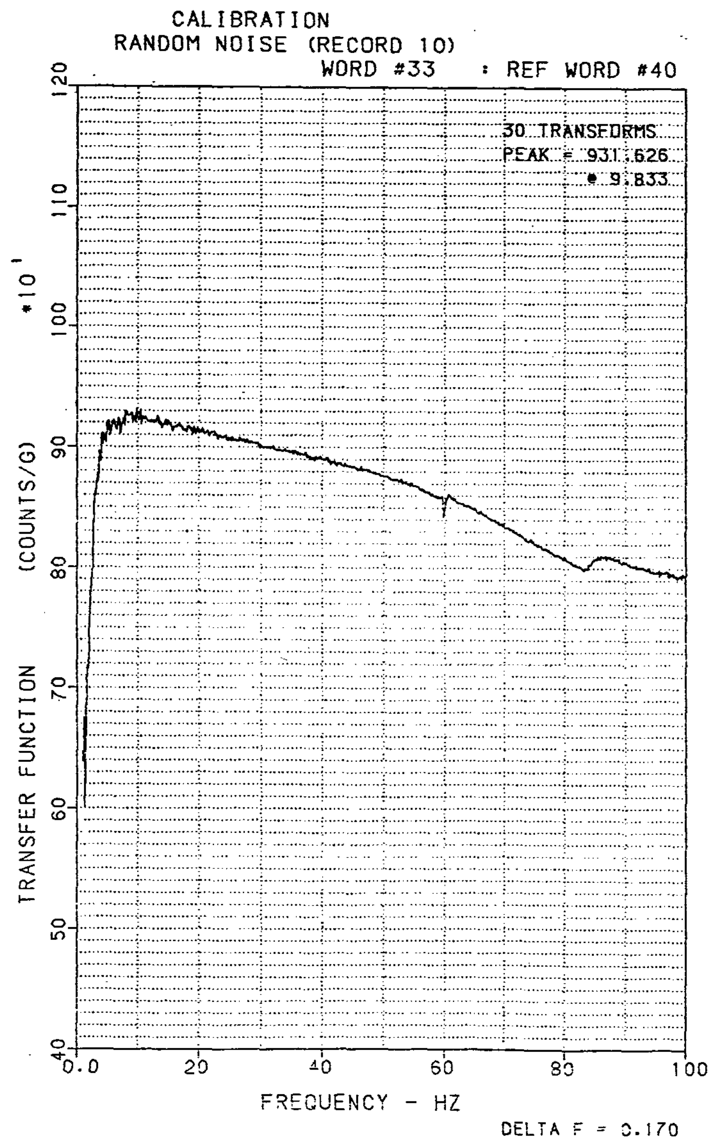


Figure 121. Transfer Function for word 33 (PCB SN 1215)

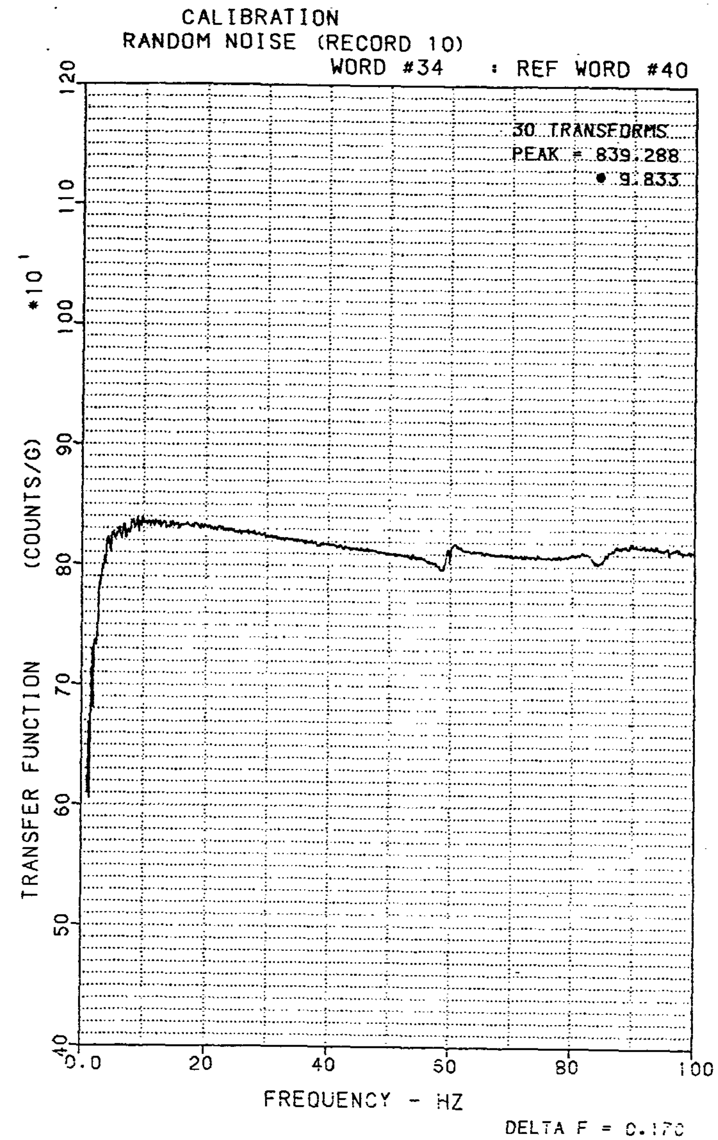


Figure 122. Transfer Function for word 34 (PCB SN 1234)

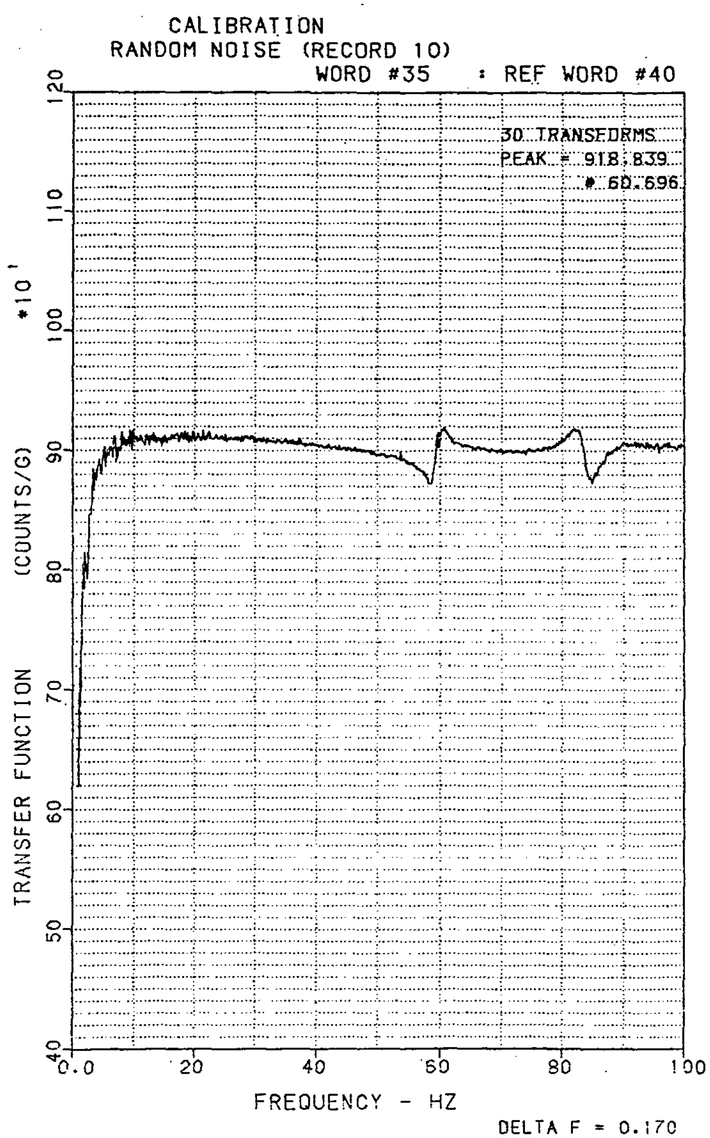


Figure 123. Transfer Function for word 35 (PCB SN 1208)

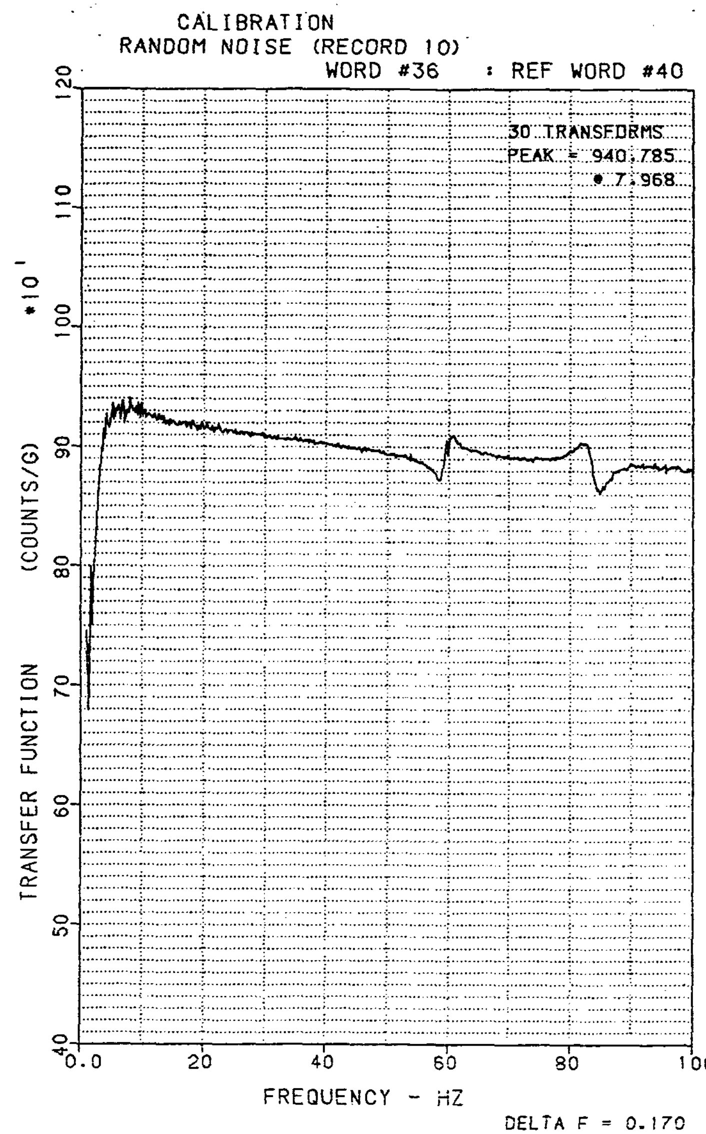


Figure 124. Transfer Function for word 36 (PCB SN 1218)

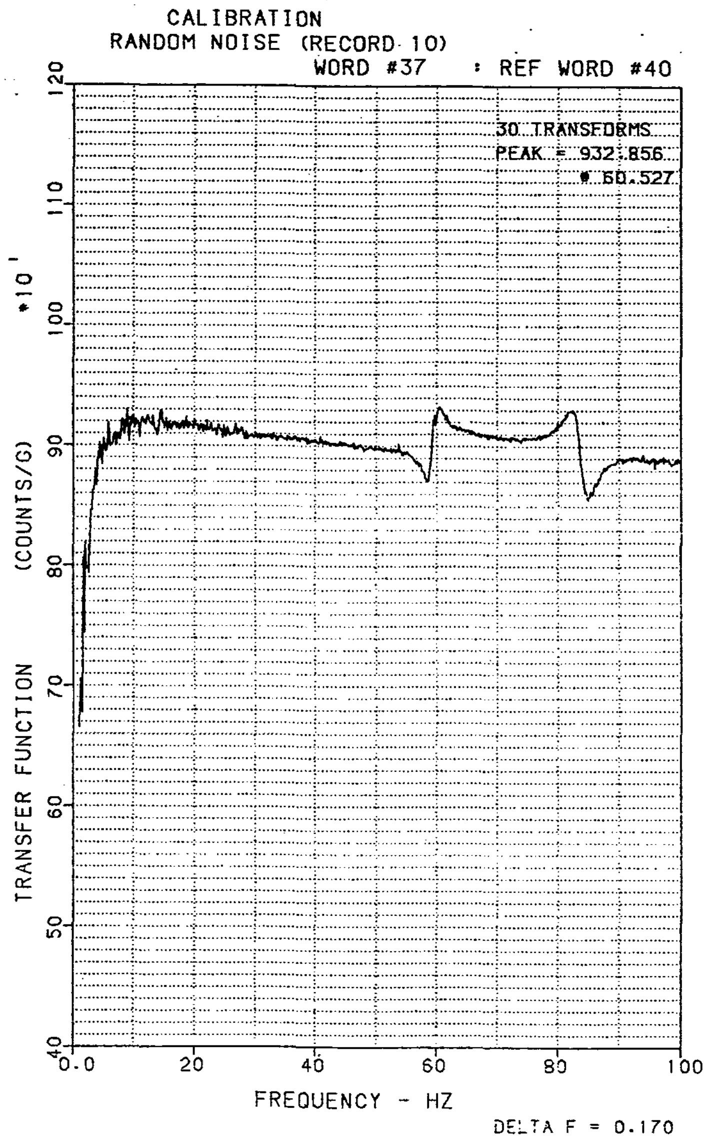


Figure 125. Transfer Function for word 37 (PCB SN 818)

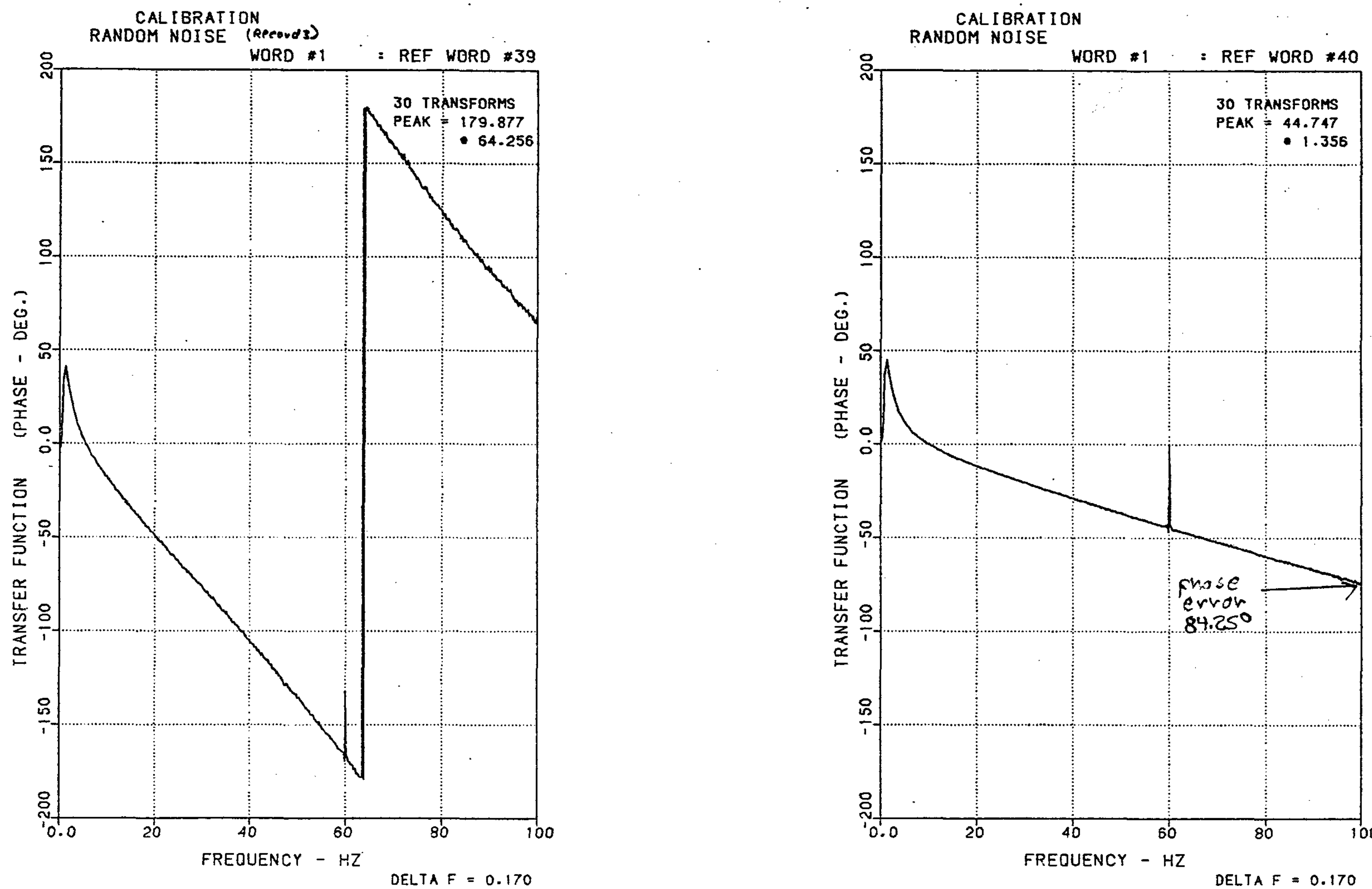


Figure 126. Typical phase responses versus word 39 and word 40

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